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CONTENTS

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PAGE

I. THE LATE HON. CHARLES STEWART ROLLS 94

II. NOTICES OF THE AËRONAUTICAL SOCIETY OF GREAT BRITAIN 95

III. GENERAL MEETING, JUNE 30, 1910:
SOME PRINCIPLES OF PROPULSION AND THEIR APPLICATION TO FLYING-MACHINES
BY B. G. COOPER 96

IV. PLAN SHAPES OF FLYING-MACHINES AND GLIDERS FOR MAXIMUM AUTOMATIC CONTROL. BY A. P. THURSTON, B.Sc. 114

V. MEMBERS' MACHINES: No. 2. J. W. DUNNE 115

VI. AIRMANSHIP IN OUR SCHOOLS. BY P. Y. ALEXANDER 117

VII. SOME SUGGESTIONS FOR A FLYING-MACHINE. BY EMANUEL SWEDENBORG (TRANSLATED BY HUGO LJ. ODHNER AND CARL TH. ODHNER) 118

VIII. NOTES 122

IX. NEW BOOKS AND PUBLICATIONS 124

X REVIEWS 125

XI. CORRESPONDENCE 128

XII. ANALYSIS OF FOREIGN PUBLICATIONS 129

SUPPLEMENT: RULES OF THE AËRONAUTICAL SOCIETY AS REVISED BY THE COUNCIL, JULY 11, 1910.

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THE LATE HON. CHARLES S. ROLLS

It is with the deepest regret that we have to record the death of the Hon. Charles Stewart Rolls who died, as no doubt he would have wished, in harness for the cause of aviation.

Third and youngest son of Lord Llangattock, Mr. Rolls was only in his 33rd year, having been born on August 27, 1877. From early youth he devoted himself to the study of mechanics: a pioneer in motoring, in the revival of ballooning, and in aviation in this country, he was one of the founder members both of the Royal Automobile Club and the Royal Aero Club, and a warm supporter of the Aëronautical Society, which he first joined in 1901.

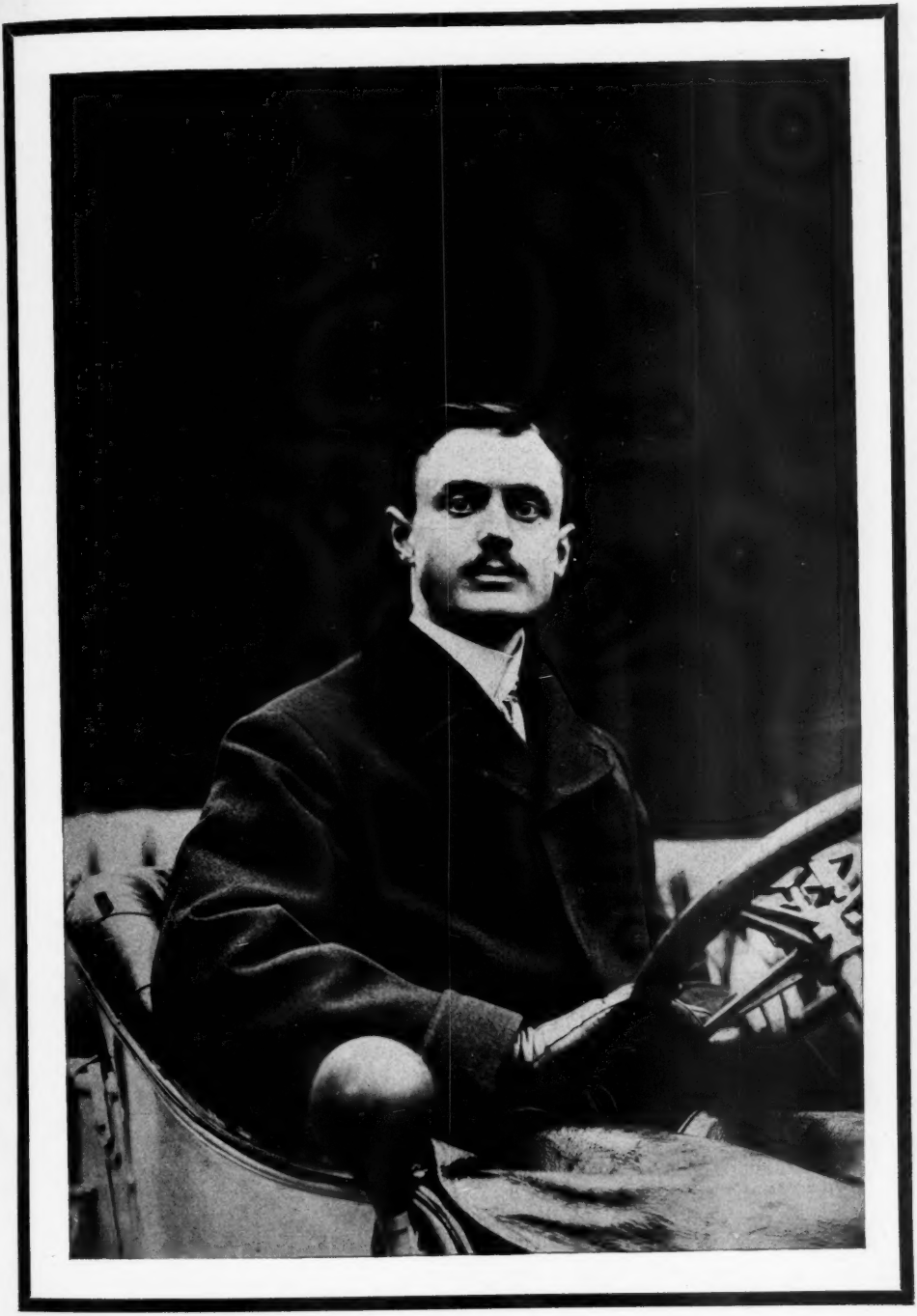
There is no need to set down once again his achievements in the three allied branches of locomotion: motoring, ballooning, and aviation; these were brilliant enough to be fresh still in public memory. It is sufficient to say that, from the very beginning, he raised himself to the foremost rank in every phase of sport to which he devoted himself. Nor is there any need to dwell on his engaging though unassuming character; but a feeling tribute should be paid to the ever-ready courtesy wherewith he was wont to extend a helping hand to those who sought his advice.

The wide young science of aeronautics could have suffered no heavier loss than that incurred by his death. Should even no monument—in any shape or form—be raised to his memory, his devoted services to the cause of aerial locomotion will ensure for him enduring fame.

Mr. W. F. Reid, of the Council, represented the Aëronautical Society at the Memorial Service held at St. James's Church, Piccadilly, on July 16. A wreath was sent to The Hendre, Monmouthshire, bearing the inscription: "With deepest sympathy, from fellow-members of the Aëronautical Society of Great Britain."

* * * * * *

The fatal accident occurred while Mr. Rolls was descending in the alighting contest, in which machines had to come to ground as closely as possible to the centre of a great circle, 100 yards in diameter, marked in front of the judge's box. He flew over the grand stand and swung easily into the wind facing his goal. Here, at a height of rather more than 100 feet, he took on a steep gliding angle and cut off the motor. The angle was very steep—about 40 degrees—and it seemed to increase as the glide continued—possibly the head-wind (15 m.p.h.) was the cause of this. At all events, the altitude of the machine became dangerous, the ground was barely 50 feet below, and there was no room to recover in following out the glide. The pilot's obvious intention was to pull up sharply into the horizontal and restart the motor. The aeroplane was a French-built Wright with a movable tail, at the rear of the rudders, which was coupled to the forward elevator and assumed a negative angle when the front elevator was put up. This was done, and for an instant the machine came level, but the sudden and enormous strain proved too much for the tail, which broke away from its left-hand attachment and hung down vertically. As an instant result the aeroplane dived head-foremost, turned right over and smashed to pieces on the ground.



THE LATE HON. CHARLES STEWART ROLLS

Notices of the Aeronautical Society of Great Britain

GENERAL NOTICES

May Elections:—Thomas Falvey; W. H. Ballantyne

July Elections:—J. D. Barclay

The following address, signed by the President of the Society, was forwarded to H.M. The King, through the Lord Chamberlain, on the occasion of His Majesty's accession:—

> "To His Majesty King George V. of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas, Defender of the Faith, Emperor of India: We, the President and Council of the Aëronautical Society of Great Britain, on behalf of the Council and Members of the Aëronautical Society of Great Britain, wish humbly to offer our condolence to Your Majesty on the great sorrow you have sustained in the death of our beloved Sovereign, the late King, and to present our congratulations to Your Majesty on your accession to the Throne and respectfully to assure you of our unswerving loyalty and devotion to Your Majesty's person."

At a meeting of the Council, held on July 11, it was unanimously decided that the Gold Medal of the Society be awarded to Mr. Octave Chanute in recognition of his distinguished services to aeronautical science.

Telegrams conveying the Society's congratulations were dispatched to the late Hon. C. S. Rolls on the occasion of his voyage across the Channel and back on June 2, and to Colonel J. E. Capper, C.B., R.E., on the occasion of the voyage of the Army dirigible "Beta" from Farnborough to London and back on the night of June 3-4.

The attention of members is called to the revised Rules, published as a supplement to the present issue, which will be brought before a General Meeting of the Society for approval.

"The Art of Flying," by Thomas Walker, has been published by the Society as No. 3 of the "Aeronautical Classics" series. "The Aerial Ship," by Francesco Lana, which will form No. 4 of the series, is now in the press and will shortly be published.

Sir William Crookes, member of the Council of the Society, is to be congratulated on the well-deserved distinction conferred upon him in the Order of Merit.

LIBRARY NOTICES

The Council desire to thank the following donors for their gifts of books and pamphlets: Dr. H. S. Hele-Shaw, Mr. Jas. Means, Professor A. F. Zahm, Mr. E. P. Frost, Mr. Lawrence Hargrave, and the Smithsonian Institution.

The following books and pamphlets have been added to the Library in addition to those mentioned under "New Books and Publications":—

da Vinci, Leonardo	*Codice sul volo degli uccelli* ...	1893
Borelli, J. A.	*De Motu Animalium* (2nd ed.)	1685
Zahm, A. F.	*Studies in Aerodynamics, &c.*	1904
Valentine, E. S., and Tomlinson, F. L.	*Travels in Space*	1902
Wilkins, J., Bp. of Chester	Works (In one vol., including "The World in the Moon," "Mercurius," and "Mathematical Magic")	1708

GENERAL MEETING

The Second Meeting of the Forty-Fifth Session of the Aëronautical Society of Great Britain was held at the Royal Society of Arts, John Street, Adelphi, on Thursday, June 30, 1910.

The President, E. P. Frost, Esq., J.P., occupied the chair.

The PRESIDENT, in opening the Meeting, said: Ladies and Gentlemen, I am very sorry to have to inform you that Major Baden-Powell's paper, unfortunately, must be postponed until a later meeting, as he has not been able to prepare it in time for to-night. I am asked to inform you that at the close of the discussion on Mr. Cooper's paper a series of cinematograph pictures will be shown. Amongst them is one of Mr. Cody's distressing accidents, which I am sure we all deeply regret. Mr. Cody has our sincere sympathy, for he has been most courageous and indefatigable in striving for success. You will all be glad to hear that he is on the road to recovery. Before calling upon Mr. Cooper for his paper, which I am sure we shall all hear with great interest and attention, I will call upon Colonel Fullerton to kindly read a letter just received from Mr. Octave Chanute, now in Carlsbad.

The letter, accepting the Aëronautical Society's invitation, was read by Colonel Fullerton.

The PRESIDENT: I have now great pleasure in calling upon Mr. Cooper to read his paper.

SOME PRINCIPLES OF PROPULSION AND THEIR APPLICATION TO FLYING MACHINES

By B. G. COOPER

There has been a very great deal written, at one time or another, on the subject of aerial propulsion, and I feel a certain amount of diffidence in venturing to add my quota to what has already been said. I am not without the hope, however, that I may be able, if not to say something new, to present old facts in a new light.

In the latter half of this paper I shall place before you some details of a novel form of propeller, but before doing so I propose to set forth what I conceive to be the functions of an aerial propeller, and to examine present types of propellers to see how far they conform to the ideal formulated.

There is a tendency at present to restrict the term propeller to a means for propelling in a horizontal plane only. This is understandable when one considers the propeller of the present type of aeroplane, or the marine propeller, but is a most undesirable restriction of function when considering broadly aerial propulsion.

Perhaps the most important advantage which aerial travel possesses over its competitors on land and sea is that it is not confined to two dimensions, but can extend freely in the three dimensions of space. That this power marks the commencement of a new era cannot be too often insisted upon. Consider what a large number of the "ills which flesh is heir to" are due to our being confined to the earth's surface. Dust, smoke, and foul air are inevitable concomitants of our herding in large cities and the toll of human life which they exact yearly is enormous. Will they have the same terrors, however, when we are able in very truth to "rise above our surroundings"? Again, consider the yearly loss of life, of money and of comfort caused by fog (which extends only a short distance from the earth's surface). Calculations have been made which show that the monetary loss due to dislocation of traffic in London alone by a single day's fog amounts to many thousands of pounds. The shipping around our coasts

is, however, the greatest sufferer from fog, as sea fogs are of such frequent occurrence. Now it will probably be some time before it will pay to use the "air road" for heavy traffic, if ever, but for passenger traffic it should soon be available. Mr. Lanchester has pointed out that aerial transit is considerably dearer than earth or water transit. It seems extremely probable, however, that for passenger traffic it will be a formidable rival to its competitors, owing to its ability to rise above the *local* weather conditions which so often cripple them. Wireless telegraphy, will, of course, have to be developed for locating purposes in the case of fogs, as is already being done for sea traffic.

I conceive it then to be of the utmost importance so to develop the propelling apparatus of the flying machine as to enable it to take full advantage of the possibilities of third dimensional travel. Flying machines must undoubtedly, if they are to have an extended sphere of usefulness, be able to rise quickly, and if necessary at an obtuse angle, from the ground. As regards the future development of the flying machine one may, I think, draw an analogy with the development of the motor-car. The great majority of motor cars are not built to carry many people. Besides the huge number of private cars of this type, public service vehicles, such as the taxi-cab, are found everywhere. Now there is not the least doubt that if we could provide an aerial vehicle capable of carrying one or two people, and which possessed the power of alighting and ascending in confined spaces such as our cities have available, we should very quickly have a fleet of aerial taxi-cabs and private cars in use. It would not be wise to anticipate a more extended use of aerial vehicles than this for the immediate present, apart from their use for war purposes, as it would not pay to use them for heavy traffic.

For use in war the machine which could rise quickly and if necessary poise over one spot would be immeasurably superior to the present form of flying machine, which is so imperfect from these points of view that its sphere is decidedly limited. It should be borne in mind that the dirigible balloon, with which the flying machine will have to do battle, can rise rapidly and vertically *if desired*.

In discussing the other day the type of aeroplane which is desirable for military purposes, a writer in one of our weekly journals stated that a machine for military use should possess the power to rise at an angle of 1 in 2 for some thousands of feet if desired. This is undoubtedly true, but the writer then went on to say that this was merely a question of engine power. This statement is most misleading, and it may be profitable to examine the capacity of the present type of flying machine for rising at an angle of 1 in 2. It may be easily shown that it cannot rise at anything like that angle in still air. We cannot consider it as being helped by wind, of course, as this might just as well be unfavourable as not.

The present type of flying machines owes its existence to the fact that it has been found impossible to obtain a high thrust per h.p. from a screw propeller of a reasonable size. The screw is able, however, to give a rapid rate of horizontal advance combined with a low thrust per h.p.* In other words, one may say that it gives out foot-pounds in which the feet preponderate. We have therefore to use a form of gearing, the inclined plane, to turn feet of horizontal travel into pounds of upward thrust. This inclined plane has usually an angle of about 1 in 10 with the horizontal, as this angle has been found the most efficient as regards lift in proportion to drift. The machine, however, cannot rise at this angle, but at one very much less, as air has to be accelerated downward before we get a reaction sufficient to sustain the machine apart from raising it. The Wright machine has a higher thrust per h.p. than most, as it uses two slow-moving propellers, but this machine has an angle of ascent of about 1 in 40 in still air. If the machine were to attempt to rise from the ground at an angle of 1 in 2, the planes would be set at about 40 degrees to the horizontal, a quite

* This is usually explained on the ground that the screw accelerates the feed stream not only during its passage through the propeller but also before it reaches the propeller, the resultant thrust being thus attenuated.

impossible angle for an aeroplane to be set at. At such an angle the drift would be more than half the lift, so that a burden equivalent to more than half the weight of the machine would thus fall *directly* upon the thrust of the propeller, and no ordinary screw propeller of reasonable size could possibly cope with it. (More especially if it had also to give a forward speed of 60 m.p.h., when required, as further postulated by the writer before-mentioned.) The diagrams (Figs. 1 and 2) show the matter graphically. In diagram 1 is shown a machine rising at an angle of 1 in 40, with its planes (represented by actual *plane* sections) set at an angle of 1 in 10. The upward reaction is represented by line *a*, and the drift by the horizontal component of this, line *b*. (This ignores frame resistance, etc.) The propeller thrust is shown by line *c*. Unless line *c* be longer than line *b* the machine, of course, cannot fly. (The relative proportions of *a* and *c* shown are those of the Wright machine.) In diagram 2 the machine is shown as if rising at an angle of 1 in 2, and as the planes are still at the same angle *to their path* as before, we have the same reaction *a*. This has now, however, a horizontal component *b*, much greater than formerly and very considerably in excess of *c*, which is the horizontal component of the propeller thrust. The machine would there-

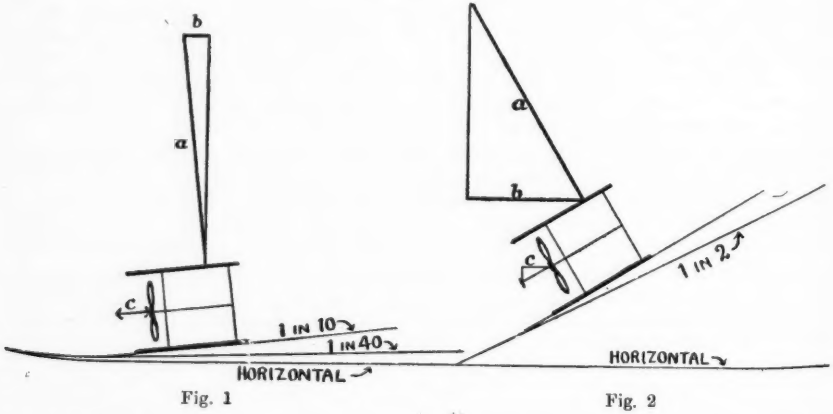


Fig. 1

Fig. 2

fore subside backwards. If we endeavour to increase *c* by increasing engine power, we also increase *a* and consequently *b*, owing to the increased engine weight. Although weight need not increase directly with power, we should nevertheless find ourselves in a vicious circle from which there is no escape with the present propeller. Unless therefore we can find a more efficient propeller, flying machines are doomed to a very limited sphere of usefulness.

It seems unnecessary to labour this point, but some writers (possibly because they consider the difficulty insuperable, and the grapes consequently sour) have argued vigorously against the necessity for abrupt rising on the part of a flying machine. They have pointed to the fact that birds in the ordinary way do not rise abruptly. This is only partly true and in any case is somewhat beside the point. It is not proposed that a flying machine should *always* rise at an obtuse angle, but only when required. Those who have studied the flight of birds under varying conditions will know that among the birds which do a fair amount of flying the majority possess the power to rise abruptly when circumstances require it. They do not use this power ordinarily for the same reason that most of us avoid unnecessary exertion.*

* The reserve of lifting power possessed by natural flyers is in many cases remarkable. The female bat, for instance, during the period of gestation, is not markedly handicapped by the considerable extra weight of her young.

Tables are often given showing the weight carried per unit area of supporting surface of birds and insects. As these tables are compiled by dividing the weight of the animal into its wing area they are merely tables of *minimum*

A wild duck or a partridge, if suddenly startled, will rise at an angle of quite 60 degrees until he has cleared obstructions, when he makes off horizontally. It is beside the point to say that in these circumstances the bird uses an inordinate amount of power. As has been shown, the aeroplane could not rise at an obtuse angle no matter what power we tried to put into it. If it could do so, the helicopter would be an accomplished fact. The bird, then, possesses an emergency power which an aeroplane does not, because his propelling apparatus is the more efficient.

To emphasise the point one may cite the case of a condor carrying off a lamb weighing nearly as much as himself. Mr. H. C. Vogt gave some figures on this point in-"Engineering" some time ago, and I cannot do better than quote them here.

> "When a condor or vulture weighing 21 lbs. seizes and lifts a lamb weighing 19 lbs. the horizontal speed cannot be above, say, 12 ft. to 13 ft. per second, else the sudden acceleration would augment the resistance too much and produce rupture. The lift during a downstroke, must, however, be so much in excess of the burden—40 lb.—as to be able to accelerate the same properly; 7 lb. extra, making the burden 47 lb., gives an acceleration of about 3½ ft. per second, if two wing strokes per second, corresponding with a centre of pressure speed of about 12 ft. per second, could be effected. More cannot be effected, because the energy . . . then stored in the wing, and again unstored twice per second, would cause extra strain and frictional loss." (The acceleration stated would give an angle of ascent of about 1 in 4.)

How is it that the condor, with a wing area of 8 square feet, moving comparatively slowly, can obtain so great a reaction as 47 pounds? At the speed given, a *plane* of 8 square feet, if driven normally against the air, would experience a reaction of about 4 pounds.

The condor is generally credited with possessing about half a horse-power. We must, of course, make allowance for its utilisation of any wind of which it might take advantage, as it is an adept at this. A comparatively light breeze would add greatly to its lifting capacity, but even making this allowance we have still a lot to account for, and certainly an admirable example to emulate.

We will now leave our condor to carry off his lamb in peace and proceed to consider the principles of which he makes such good use, and which we must bear in mind when designing aerial machines.

Whatever may be our theoretical conception of propulsion in fluids, the fact remains that, in practice, it involves the projection "astern" of a mass of the fluid. This fluid flows or is drawn into the propeller on the feed side, is accelerated during its passage through the propeller, and leaves on the delivery side. Now it will doubtless be generally conceded that the most efficient propeller would be that, other things being equal, which would impart to the fluid the acceleration necessary to obtain the greatest reaction therefrom, without otherwise disturbing it. That is to say, the fluid on the feed side, advancing in a straight stream, would be accelerated to the necessary extent and leave the delivery side in a similar straight stream without needless diversion. In addition our ideal propeller should be one which possesses "flexibility" (in the steam-engine sense). That is, it should be able to meet, equally efficiently, widely varying conditions of load. (Ideal efficiency in this direction would imply the capacity to move, by means of one horse power, either 33,000 pounds a distance of one foot in one minute, or one pound a distance of 33,000 feet in the same time. This ideal

weight carried, and often afford but slight indication of the *maximum* capacity for weight lifting. It is most important to bear this fact in mind when comparing natural with artificial flyers. Dr. Pettigrew made some interesting experiments to determine the effect of removing portions of the wing from certain insects and birds. These are too long to detail here; they may be referred to in his book on Animal Locomotion. Two most remarkable facts arrived at are that the posterior *two-thirds* of the wings of a blue-bottle fly may be removed without impairing flight, and that either pair of wings of a dragon fly may be dispensed with.

is, of course, quite visionary, as it ignores the factor of aerial resistance to travel, but we can at least get a little distance thither.) To make use of a "flexible" propeller we, of course, require an equally flexible power plant. Unfortunately, the internal combustion motor possesses no flexibility in the steam-engine sense, but we can patch up the deficiency by means of a gear-box, as in a motor car. In addition to possessing flexibility, our propeller should be capable of giving its thrust, as required, in any of the three dimensions of the atmosphere.

This latter property, besides enabling us to turn easily in any desired direction, would also enable us to maintain equilibrium in even the most erratic winds, provided it were sufficiently rapid in application.

This raises the question of automatic versus controlled stability, and a short digression on the point may be excusable.

An automatically stable flying machine in disturbed air would be such that the same gust of wind which, by striking part of it, tended to make it unstable, would, by purely unaided action on the same or another part of the machine, maintain stability.

It is doubtful whether a flying machine could be made automatically stable in the above sense under all *possible* weather conditions, short of endowing it with the form and speed of a projectile. Within practical limits, however, automatic stability can, of course, be attained to a high degree. That is, if the machine be practically inert save for onward movement. If various parts be moving relatively to one another, such as wings and body in a bird, the problem of automatic stability in the sense given contains too many variables to give hope of a successful solution. Controlled stability therefore affords the best solution in this case.

Controlled stability can be attained by either of two main methods, or by combinations of the two. One method is to do everything "by hand," the other is to have automatic machinery to take the place of brain and hand, giving a form of automatic stability in a sense different than that used before.

The solutions of the stability problem arrived at by natural flyers such as birds are like all evolutionary processes, compromises. Some birds possess automatic stability in a high degree when gliding, others very slightly, but all have controlled stability in varying degree. This is due to the fact that they are not inanimate pieces of matter, but all possess brains, which, like ourselves, they use to a greater or less degree.

Two interesting birds to study in this connection are the common gull and the ordinary domestic pigeon. They represent two divergent types of development in regard to stability. The gull is automatically stable to a great extent. Long ages of evolution have so formed him that he is able to float in turbulent air currents without having to use his brain to any extent to look after his stability. He is thus able to devote his whole energies to searching the water beneath him for something edible. If he did not possess this capacity he would quickly die of starvation. It will be found in accordance with this condition that birds, which have habitually to get their living while on the wing, possess greater automatic stability than those which have not to do so.

The domestic pigeon has his meals provided for him in comfort. He is not compelled to hunt for food in all weathers like the gull. He has consequently evolved a different solution of the stability problem. His brain not being occupied in the search for food, he is free to think about stability, and his stability is chiefly controlled, not automatic. When we watch a pigeon using his wings we can see that he is thinking about it. The peculiar half strokes he gives at times and his unequal beats show this very clearly. One can see his brain working hard when he glides. When a gull glides he does so in an effortless, nonchalant manner. His dihedral angle is usually negative, and his centre of gravity about in the same plane as his centre of pressure. Not so the pigeon. His dihedral angle

is, in anything of a wind, very positive; so much so that his lifting capacity is very considerably reduced. He likes to feel his centre of gravity very much below his centre of pressure, and one can see him consciously correcting for stability when a gust strikes him. He cannot be said to be a good glider. One can see that, when gliding, turbulent winds worry him very much. We cannot say, however, that he is not a good flyer, as some of the properly attested flights of homing pigeons are wonderful feats of speed and endurance. He simply exemplifies the fact that there are several different ways of flying.

Having regard to the fact that automatic stability is only attainable between limits, we must always have controlled stability to a certain extent in our flying machine (not necessarily hand-controlled, of course). In these circumstances it merely becomes a matter of experience to say to what respective degree automatic and controlled stability should be employed. Controlled stability has the advantage that it can do all that automatic stability can do and more.

The most potent form of controlled stabiliser is undoubtedly controlled direction of propeller thrust, as is used by all natural flyers to a greater or less extent.

To sum up our ideals then, we have to find the propeller which will give us the best result for the least work, as a propeller in a horizontal direction, which will also be flexible in the steam-engine sense, and which can be controlled as to direction of thrust. From a commercial point of view there are, of course, other factors to be considered, such as cost of manufacture, durability, and so on, but these are subsidiary considerations to us as a Scientific Society.

Examining first the jet propeller, we find that it can certainly accelerate a feed-stream without undue diversion, but its efficiency is very low. There are three conditions to be met in order that jet propellers may be successful: (1) We have to get energy into the fluid we are using; (2) we have to get the fluid to the jet with this energy still in it; (3) we have to utilise all the energy in the fluid at the jet. It has been found impossible to fulfil these three conditions at one and the same time. If we use in our jet the fluid in which we are immersed, we have to do so much work on that fluid before it is discharged at the jet that all-over efficiency is very low. (The jet itself in these cases is not so much at fault. Mr. Barnaby estimated the efficiency of the jet in the Thornycroft water-jet propeller as over 70 per cent., and claims for over 80 per cent. have been advanced for other jets.) On the other hand, we can generate an energetic fluid such as steam or hot gases without much loss, but we lose so much energy in the form of unutilised heat at the jet that we are not better off than before. Jet propellers have been uniformly failures, although they could probably be made flexible and can certainly give their thrust in any desired direction with ease.

Failing jet propellers for propulsion we are confined to some form of moving blade, and have to discover the most efficient method of actuating it. It is obvious that we cannot move it continuously away from us, we must carry it with us, so we have to make it perform some sort of journey relatively to our vessel. What is the most profitable journey on which we can send it?

The simplest and most obvious way of actuating a blade is to use it as a paddle. This involves a similar movement to that which we make when walking. A natural example of such a propeller is the web-foot of certain birds. This propeller may be called the reciprocating paddle. As is the case with all air propellers, we cannot, of course, avoid total immersion; the return stroke of the paddle must therefore be made in a feathered manner, either along the same path as the active stroke or closely adjacent thereto. Not only is the blade doing no effective work during the return-stroke, but it is setting fluid in motion in the wrong direction. General efficiency is therefore not high, and there does not appear to be much ground for anticipating a future for this type of propeller, although it can be made flexible, and its direction of thrust can be controlled easily.

The de la Hault wing movement is a form of paddle worked by a very ingenious mechanism. I understand that a certain degree of success has attended this apparatus, but the idle return-stroke of the wing renders a *high* efficiency improbable.

This wing movement is really a form of revolving paddle, but has the characteristic defect of the reciprocating paddle, so I have mentioned it here. It also leads us naturally to the rotary and semi-rotary or oscillating propellers. In all these the blade revolves round or oscillates from a fulcrum, and therefore must of necessity set up centrifugal action in the air surrounding it, causing such air to flow away from the fulcrum. Other things being equal, this centrifugal action will be greatest when the blade is most nearly normal to its path. In any case it must be reckoned with, and if possible utilised. The research into the increase of reaction against a revolving plane as compared with that moved inertly in air has not been so full as could be wished. Enough has been done, however, to show what a potent force for increasing the reaction this centrifugal flow is. In the case of a plane normal to its movement the centrifugal flow when the plane is revolved sets up an entirely different system of stream lines around the plane from those which obtain when it is not revolved. At similar speeds of movement of the mean mass of the planes the reaction is several times greater against the revolving plane than the other. It is interesting to recall in this connection that Gustav Lilienthal has recently obtained a reaction against a beating wing of 7 times more than, as he puts it, "the general calculation otherwise shows." By the general calculation I presume he means the formula for normal impingement on a flat surface.

It is obvious that the increased reaction is due to a certain extent to the fact that the speed of each part of a revolving plane varies simply as its distance from the axis of revolution, whereas the resistance against it varies as the square of the speed. The increase due to this cause would be proportional to the amount by which the mean square of the speed exceeded the square of the mean speed. This increase is, however, only a slight portion of the actual difference found experimentally between the reaction upon the revolving and the inertly moving plane. The difference is undoubtedly due chiefly to the centrifugal action of the revolving plane. This fact has a most important bearing on the question of how best to actuate our moving propeller blade. It is obvious that anything which reduces the speed of travel of our blade while giving a greater reaction, reduces also the amount of non-productive work we have to do.

It is by no means easy to utilise the centrifugal action of revolving planes, as will be seen when we approach existing types of propellers from this point of view.

The most obvious way of utilising the centrifugal action of revolving blades is to use a centrifugal pump. As a means of obtaining propulsive reaction, however, a centrifugal pump is not at all efficient. Air is being thrown from the blade tips through the 360 degrees of their movement and as only that discharged through about 130 degrees can be utilised in any one direction without diversion, the casing is used to divert the rest. Besides the objection to the bulk and weight of the casing, it causes most serious losses (due to friction and eddy formation within the casing). It does not seem possible to overcome these objections.

A somewhat analogous propeller to the centrifugal pump has been proposed. Blades are fixed normally radiating from a shaft. To one edge of the blades and concentric to the shaft is fixed a disc. On setting the blades in motion the air is thrown outwards from the shaft and the resulting rarefaction, being on one side of the disc, causes it to move towards such rarefaction. As the feed stream is absolutely diverted in a direction at right angles to the direction of propulsion efficiency would probably not be high. A casing could, of course, be used to redivert the delivery stream, but this would be reverting to the inefficient centrifugal pump.

The number of proposed aerial paddle wheels is, of course, great. In some cases they have ordinary radial paddles masked to a greater or lesser degree, but usually they have some sort of feathering action so as to render the idle return-stroke of the paddle as short as possible. There is one form which was originally invented many years ago, and has been re-invented many times since, which has theoretically no idle return-stroke at all. I have a quasi-paternal interest in this wheel, as I re-invented it myself some years ago. It is shown in the diagram.

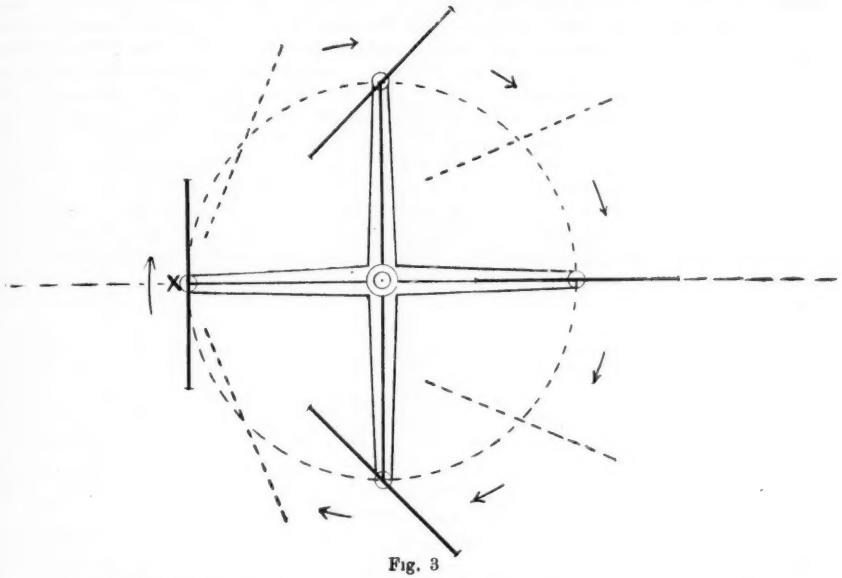


Fig. 3

It will be seen, by following the blade round its orbit, that whatever position it occupies in such orbit there is always a component of its pressure reaction which points in an upward direction, except at the dead-point X.

The direction of thrust can be varied at will in a plane at right angles to the shaft.

This is the most promising of the aerial paddle-wheels, but only test can show to what extent it is free from the great defect of all totally immersed paddle-wheels, namely, their churning action on the fluid. This defect renders it impossible for them to accelerate the feed stream without doing a large amount of unnecessary work on it. In addition, the rarefaction due to centrifugal flow exists round the shaft where it is very difficult to utilise it. These objections could be met to a certain extent by making the blades small, and few in number relatively to the size of their orbit, but this would entail a cumbrous and heavy frame relatively to the reaction obtained.

It has long since been realised in the case of water that no form of paddle-wheel is efficient when totally immersed, however we may mask or feather the blades, and there seems little reason to anticipate a different result in the case of air.

Of the purely rotary propellers we have now Mr. Porter's, and the screw propeller. Mr. Porter's propeller is, I believe, founded on a suggestion of the late Mr. Wenham, that a casing should be affixed to a sort of fan-blower in such manner as to divert the discharge in a direction parallel to the shaft, instead of

at right angles to the shaft, as in the ordinary fan-blower or centrifugal pump. I an not aware what degree of success has attended Mr. Porter's efforts. We shall doubtless hear in due course.

We now come to the screw-propeller, which has for many years past been the most widely used form of propeller for marine work (and has consequently been more or less tacitly accepted as the best for aerial work). It has not supplanted the paddle-wheel by virtue of superior efficiency as a propeller simply; it is, if anything, less efficient from this point of view than the paddle. Where, however, it has the advantage is that it can be coupled direct to a much faster engine than can the paddle, and it is also less cumbersome. The screw has been found, in marine work, to be only relatively efficient. An enormous amount of work has been done to try and increase its efficiency, but with only slight success. The best screws nowadays are only slightly more efficient than those of many years ago, and this increased efficiency is due chiefly to improved methods of manufacture, not radical improvements. In most favourable circumstances an efficiency of about 70 per cent. is all that can be expected. Average efficiency is, of course, much lower than 70 per cent. It is interesting to recall that a famous naval man once said that if one took two pieces of boiler iron and stuck them on the boss at the right pitch angle, one would get within a knot of the best marine screw made. Curtiss won the speed prize at Rheims with a propeller the blades of which had the same angle to the shaft throughout their length; they had no helical form at all.

Having regard to the innumerable forms of screw propeller which have been tried, it seems reasonable to conclude that the losses to which they are subject are inherent in the type, and are not to be removed by tinkering with details. Thirty per cent. of the power is a large proportion to waste, and the value of a practicable propeller which should give a higher efficiency would be incalculable.

Under present natural conditions, of course, no propeller can possibly be made that will waste no power at all; there must be a certain amount of loss. Some of that 30 per cent. should, however, be recoverable.

There are several sources of loss in the screw propeller. They are still the subject of controversy, into which we will not enter. It will suffice to mention a few here. In the first place the fact that during acceleration the feed stream is permanently diverted from its path must undoubtedly cause loss. The discharge from a screw propeller consists of streams of fluid which have a helical form, and the wake as a whole possesses rotation. The energy which goes to perform this "rope-spinning," as Professor Fitzgerald termed it, cannot be effectually recovered. Attempts to do so by means of turbine blades and so forth have introduced fresh sources of loss and have not succeeded. It is generally admitted that this rope-spinning does lead to loss, although some investigators have declared it to be negligible. In the second place a source of loss in the screw-propeller is the fact that the centrifugal flow set up by the revolving blades is at right angles to the direction of propulsion, and cannot *per se* assist in such propulsion. The revolving action of the wake also causes a region of reduced pressure to exist along the core of the column of fluid, owing to centrifugal force, and this, of course, is another source of loss. This phenomenon can be studied in Professor Flamm's photographs of screw propellers in water. In some cases the reduction of pressure is such that an air cavity forms down the centre of the wake, forming a sort of air-hose appendage to the boss.

In any case, whatever the causes, the fact remains that that 30 per cent. is wasted.*

* Shortly after M. Bleriot flew the Channel, a claim was advanced on behalf of the propeller which he used, that it had only 15 per cent. slip. It seemed obvious, from the emphasis which was placed on this statement, that it was intended to suggest that the efficiency of the propeller was 85 per cent. Many strange conceptions exist on the question of efficiency in relation to slip, but many other factors have to be taken into consideration before a certain percentage of slip can be said to tell us what the propulsive efficiency of a propeller is. This slip, as given, was doubtless the difference between the observed speed of advance of the propeller and that calculated as possible by multiplying the pitch by the revolutions. If this pitch was calculated on the angle of the so-called acting face of the blade, ignoring the rounded back, as is often done, it was of course, understated.

The only real test of the propulsive efficiency of a propeller is to compare the foot-pounds which come out of it with those put into it. Judged by this standard the screw is undoubtedly unduly wasteful.

In what case does the screw stand as regards flexibility? It is evident that no rigid screw can possess flexibility to any extent. Its pitch and diameter being invariable it cannot adjust itself to different rates of advance and conditions of thrust. Therefore, although it is possible to design a rigid screw propeller to give a maximum efficiency of between 60 and 70 per cent. at a certain pre-determined rate of advance and revolutions, efficiency falls off either side of the pre-determined point. (Losses due to variation of the above factors are, of course, not confined to screw propellers.)

If, however, we had a screw propeller with not only variable pitch but variable diameter (which would, of course, imply variable blade area), we should be able to attain a very considerable degree of flexibility. There have been many variable pitch screws invented, and some with variable diameter. They do not, however, appear to have been developed, probably owing to mechanical difficulties. The thrust of a screw varies as the square of its diameter, and such a propeller as described would have the great advantage of giving us a very high initial thrust and consequent ease of starting of our machine. Owing, however, to the fact that in the aeroplane the screw revolves in a vertical plane, we very soon reach the limit of our possible increase in diameter. We could use a number of small screws, but this introduces formidable mechanical difficulties in driving them.

If it were possible to obtain, with a screw propeller, a high static thrust per horse power, we should, of course, be able to make very satisfactory helicopters, for as the plane of revolution is in these machines, horizontal, we are only limited as to diameter by considerations of strength of material.

It is evident, of course, that with any propeller our thrust per horse-power varies with our rate of advance. The limit of our possible thrust per horse power at any given rate of advance is found by dividing 550 by the rate of advance in feet per second (550 being the number of foot-pounds per sec. in a horse power).

From this it will be seen that at a rate of advance of 1 foot per sec., the highest possible thrust per horse power would be 550 pounds; at 50 feet per sec. it could not exceed 11 pounds per horse power. This obvious and important fact is often lost sight of when dealing with propellers. If we could produce a propeller of which the thrust varied inversely as the rate of advance, it would, as before said, be ideally flexible. The rigid screw propeller is about as far from this ideal as a propeller could possibly be.

The direction of thrust of a screw propeller can, by means of suitable gearing or flexibly jointed shafts, be varied at will. The mechanical losses introduced are, however, not small, and the valuable effect of variable direction of thrust in quickly correcting for stability could not be fully utilised with rapidly-revolving screw propellers. The gyroscopic action would resist sudden deflection of the plane of rotation.

Several dirigible balloons, including the last army airship, have been fitted with "orientable" propellers, as the French term them, and these have given an indication of the value of controlled direction of thrust.

Bearing in mind the manifest imperfections of the screw propeller it can obviously survive only for want of something better with which to replace it. I hope to be able to show that there is in existence a better propeller, which only awaits development. This is the oscillating propeller.

All the "natural" propellers, such as those of birds, insects, fishes, and so forth are oscillating propellers for the primary reason that no living organism can possess a rotating part. For this reason all the organs of movement of living things are oscillating. It having been found advantageous to replace this prin-

ciple of oscillation by one of rotation when making artificial organs of movement on land, it has been erroneously concluded that it would necessarily be found equally advantageous to adopt a rotary propeller for propulsion in fluids. There is, however, no true analogy. Although the function of the ordinary water propeller is analogous to that of the wheel, in that it propels in two dimensions only, the case is quite different when we are, as in aerial propulsion, totally immersed in the fluid and have to find a means whereby to travel easily in any of three dimensions, while maintaining our equilibrium during fluid disturbances.

For land propulsion it is very difficult to fashion an artificial limb so that it will work as freely and smoothly as a natural one, and as the earth's surface is so inelastic, the wheel is superior even to the natural limb when it is a question of obtaining a rapid rate of advance free from shocks. In obtaining this smooth rate of advance by means of a wheel, however, we have to sacrifice the many varied movements of which the limb is capable, and confine ourselves to one, that of rolling along a specially prepared track. When we want a machine capable of travelling rapidly over rough country or of jumping ditches and hedges, we take a horse, not a motor car.

Now, we are able to do a good many wonderful things, and it is perhaps rash to venture to place a limit on our possible achievements, but I think few will be prepared to claim that we shall ever be able to maintain smooth prepared tracks, like roads, in the air. We cannot macadamise the atmosphere, or lay down rails on it. We must always be prepared to negotiate hilly and rough "air-country." Besides, now that we have this new and delightful territory open to us, it seems unreasonable to restrict ourselves to rushing through it with the speed of an express train, incapable of slackening our tearing pace for fear of disaster. We want to take full advantage of our new country, and therefore what we want for flying is not a propeller of single function analogous to the wheel, but a propeller of varied function analogous to the limb.

The only propeller which can efficiently meet the case is the oscillating propeller. We will take, firstly, its efficiency as a propeller simply. Fortunately, we are able to refer to some valuable data on this point. In "Engineering" of 31st July, 1908, Mr. H. C. Vogt gives some details of trials which were made with a 200-ton schooner in order to ascertain the relative efficiency of a screw propeller and an oscillating propeller of Mr. Vogt's invention. These trials, which were conducted under the ægis of the Danish Admiralty and Institute of Civil Engineers, may be taken as reliable. They showed the oscillating propeller to be 10 to 15 per cent. superior to the screw. That is, the oscillating propeller returned in useful work at least 10 per cent. more of the power put into it than the screw, although the screw gave what was considered a fine result.

The oscillating propeller was of quite simple construction, being a mechanical reproduction of the action of an oar when used as a propeller over the stern of a boat. That is, the blade oscillated in one plane at a varying angle to its path. The direction of thrust could be varied at will in a horizontal plane, and the propeller therefore performed also the functions of a rudder, and much more efficiently than the ordinary dead rudder. This was done without affecting its propulsive efficiency.

Mr. Vogt states that with his propeller a man has been able to obtain nearly double the static thrust which he could obtain with a screw even of large size, in air and water. This shows its superior flexibility as compared with the screw.

In "Engineering" of 25th September, 1908, Mr. Vogt goes further into the matter and gives a mathematical proof of the superiority of the oscillating propeller. I have not seen his arguments refuted. He gives as the reason for the superiority of the oscillating propeller the fact that it can accelerate from a lower velocity a greater quantity of fluid than can a screw propeller, power for power. The importance of accelerating fluid from as low a velocity as possible has, of

course, long been recognised, as has also the fact that the screw falls far short of this ideal. Rankine defined the most efficient propeller in the following terms:

> "If the propelling instrument be so constructed as to act upon each particle of water at first with a velocity equal to the velocity of feed, and gradually increasing at a uniform rate up to the velocity of discharge, then the loss of work is the least possible."

The reciprocating paddle, during its active stroke, approaches very closely to this limit, but loses, as before-mentioned, during its return-stroke.

When advancing through the fluid, Mr. Vogt's propeller is able to impinge upon fresh fluid in each swing by virtue of being a high-pitch, slow moving propeller. When not advancing, its high static thrust is due to the fact that whatever transverse velocity has been imparted to the fluid by virtue of the high pitch in one swing, adds to the reaction against the blade upon the return swing. It is not, as in the case of the screw propeller, quite lost. The transverse velocity imparted to the fluid by a screw propeller cannot be recovered in the same manner as in the oscillating propeller, as it is continuous in one direction, and attempts to recover it by means of turbine blades have, as before said, introduced fresh sources of loss.

It has been found when starting-up screw propellers under power that the thrust is considerably greater while accelerating the fluid from zero velocity than it is when a steady stream has been set in motion. This is, of course, quite understandable. Now, if it were possible to reverse the pitch and direction of revolution of the screw, without loss, immediately the initial thrust commenced to fall off, we should keep that initial thrust up to nearly its maximum. We should then, of course, have an oscillating propeller.

There is not the least doubt as to the superior propulsive efficiency of the oscillating propeller. The difficulties that occur, and which have up to the present prevented its development, are mechanical, in connection with driving it. We will examine these.

The difficulties which occur when coupling a slow-moving propeller to a fast moving shaft may be ignored, as they are not confined to oscillating propellers, and can in any case be overcome by the use of gearing in the case of flying machines, where the powers transmitted are not high.

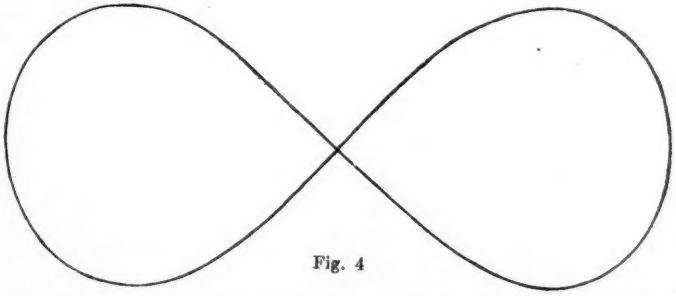


Fig. 4

There are, however, two other difficulties. We have in the first place to make our oscillating propeller light and yet strong enough to stand its own oscillations. In the second place we have to make a simple and compact gear whereby to transform rotary into oscillating motion. The solution of these two difficulties which I have essayed I will now describe.

In my oscillating propeller the blade oscillates in a figure-of-eight curve, the average plane of oscillation lying along the major axis of the 8. The diagram shows the actual trace made by the blade axis of one of my models.

We will examine in the first place the mechanical aspect of the blade orbit.

We noted before that the blade of any propeller cannot continue travelling indefinitely in one direction, it must perform some sort of orbit. Its momentum in any one direction must therefore be damped out in order that it may return to the place whence it started relatively to the machine to which it is attached. The purely rotary propeller is in the most favourable position in this regard, as the absorption of momentum and reversal of motion of the blade-mass are spread over the greatest period of time, and, being continuously effected, cause no fluctuation of effort. The propeller, which is the most unfavourably situated from the present point of view, is that oscillating propeller wherein the blade oscillates in one plane, the motion of the blade-mass being completely stopped, and restarted in the reverse direction, between each oscillation. Unless the blade be swinging pendulum fashion at a rate governed by its period as a free pendulum, the momentum of the blade-mass is, in this propeller, completely absorbed in the shortest space of time, and in any case the actuating mechanism is called upon to bear the greatest fluctuation of effort. (Despite this objection, we have seen that this form of propeller has a superior propulsive efficiency to that of the screw.) Although the air forms a yielding abutment and minimises shock, the above characteristic of the ordinary oscillating propeller has proved the rock upon which most of the proposed flapping wing machines have up to now been wrecked. It has been found impossible to make a flapping-wing strong enough and light enough to enable it to store up in itself between its swings the energy imparted to it during its swings.

It cannot, of course, be expected that any oscillating propeller can obtain the smoothness of action of a screw propeller. We can, however, always balance inertia forces acting on the machine by running our oscillating propellers in pairs, so that we need chiefly to confine our attention to obtaining an oscillation which will minimise strain on the propeller mechanism. The figure-of-eight oscillation is, relatively to the area swept by the blade, the best we can adopt from this point of view. Absorption of momentum and reversal of motion of the blade-mass are performed gradually and the mechanism is not subject to extreme fluctuation of effort. When the orbit is of the proportions shown in the diagram, the speed of travel of the blade-mass is approximately uniform, and the kinetic energy therefore constant. We shall have some slight additional friction loss in the mechanism due to changing the direction of motion of the blade-mass more frequently than in the rotary propeller, but as, in my mechanism, the number of bearings is very small and ball-bearings can be used throughout, mechanical efficiency should approach 100 per cent.

We now turn to the gear by which the blade is driven in the figure-of-eight orbit (off a rotating shaft) and find that, rather unexpectedly, by adopting the 8 orbit, we have a simpler gear than if we oscillated the blade in one plane. As will be seen from the figure, the simplest form of the gear consists of only *three* moving parts. We have the blade shank *a*, with an arm extending therefrom a^1, which is embraced by a bearing in the crank *b*, and we have some means, such as the fork *c*, to enable the blade to swing without rotating round the power shaft. I cannot conceive it possible to make a simpler oscillating propeller than this. In addition, there is nothing freakish about the mechanism; it is on sound and simple mechanical lines.

A further great advantage which we obtain by means of this mechanism is that we are able to control without difficulty or complication the direction of thrust of the propeller. If we make the bearing of the fork *c* revolvable in a controlled manner round the axis of the power shaft, we can direct the propeller thrust anywhere in a plane at right angles to that shaft. A worm and wheel is all that is required to control the position of the fork bearing. We thus obtain an "orientable" propeller without the intervention of any bevel gears or universal joints at all. The mechanical efficiency is not reduced by our directing

mechanism, which enables the propeller to be reversed without affecting the power-shaft.

By making the throw of crank *b* variable, and this can be done quite simply, we have a mechanism which gives a variable amplitude of oscillation while working. That is, the orbit can be varied from a maximum down to zero without stopping the power shaft.

Quite a simple mechanism can also be made which makes it possible to turn the major axis of the eight in any direction. This enables us to direct the thrust of the propeller anywhere in a plane parallel to the power shaft, instead of at right angles thereto as formerly. We can by this means also entirely reverse the propeller thrust without reversing the power shaft. By a suitable use of these mechanisms on our flying machine or dirigible balloon we should be able to direct a thrust in any desired direction and obtain a control of steering and equilibrium at present unattainable.

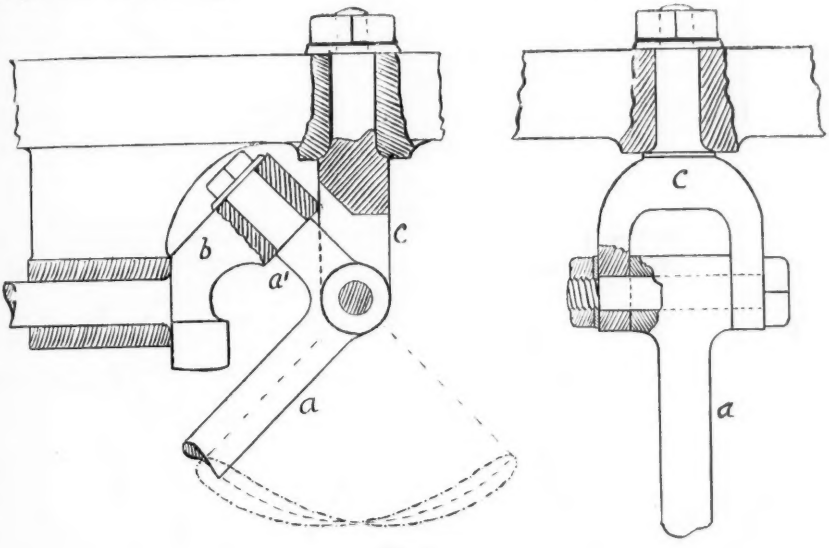


Fig. 5

It now only remains to consider in what manner we shall feather our blade while it is travelling in its orbit.

If we feather it in the same manner as Mr. Vogt during his oscillation in one plane, we shall obtain a feathering as shown in the diagram. It seems reasonable to anticipate that the propulsive efficiency of such a propeller would be in every respect equal to that obtained by Mr. Vogt's propeller, with the added advantages of a direct drive off a revolving shaft, and less strain on the mechanism.

By placing the major axis of the orbit vertically, and using a flexible wing, as shown in the diagram, we obtain an action analogous to that of a bird's wing, that is, we get downward thrust combined with backward thrust. This wing action is free from shock or jar, and thus avoids one of the greatest evils of flapping-wing mechanisms.

The feathering shown is founded on that of the Vogt propeller, but it could, of course, be as shown in Fig. 8. It would then be similar to that given by Pettigrew or Marey as a result of their investigations into the action of natural wings.

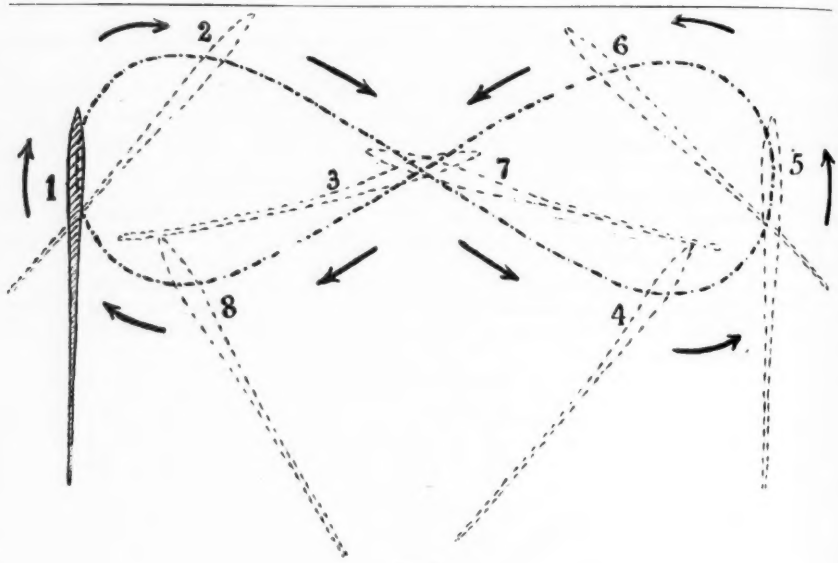


Fig. 6

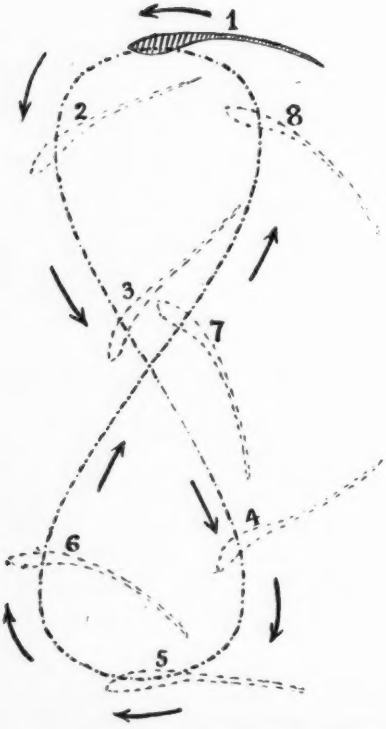


Fig. 7

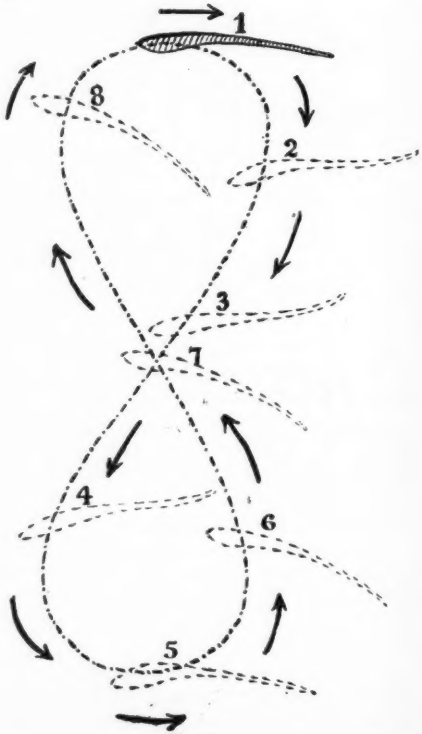


Fig. 8

In the case of the feathering shown above, the blade, besides travelling round the orbit, pivots on its shank, such pivotal movement being spring-controlled. It

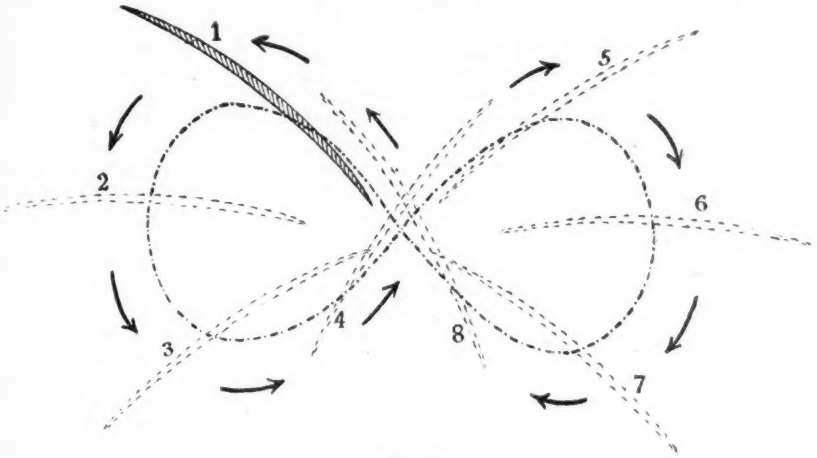
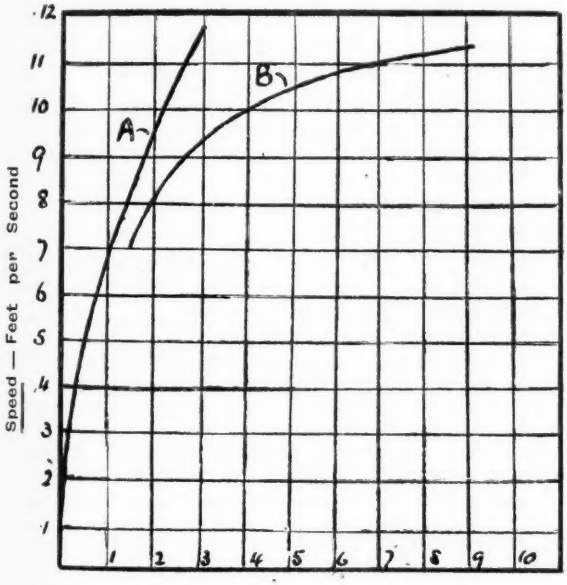


Fig. 9



This Diagram

shows relative Size of Blade and Orbit in these tests

Fig. 10

can, however, be rigidly affixed to the shank so as to give the feathering shown in the diagram (Fig. 9).

It will be seen that at the extremities of the orbit the blade acts upon the fluid like an oar or paddle, which as we noted before, most nearly approaches, during

its active stroke, Rankine's Ideal Propeller. The loss which occurs during the idle return-stroke of the ordinary oar or paddle is, however, entirely avoided in this propeller, as there is no idle return-stroke. The blade, during its return-stroke, travels in an inclined manner along a diagonal path, and gives a reaction in the same direction as during the forward swing. A most important advantage which accrues is that the blade impinges upon entirely fresh fluid in each half of its orbit. In addition, the centrifugal flow, which so augments the reaction against a swinging plane, is utilised to the utmost. The propeller is unique in this respect.

Having regard to the above-mentioned features of the blade's travel, we should naturally expect the static thrust of this propeller to be high, and this has been demonstrated experimentally to be the case. The diagram (Fig. 10) shows a test result obtained with a small model.

I had hoped to be able to show to-night some models of various forms of the propeller, and give details of quantitative tests with them. The development of this invention, however, like many others, has been retarded by lack of capital, and I have only just lately been able to make arrangements for having the necessary models made. If all goes well I shall have some interesting results to lay before you at some future date, when I hope to go fully into the action of the blade upon the air. For the present I will merely ask you to consider to what a large extent the oscillating propeller is able to utilise the centrifugal action of a swinging plane. No other propeller is able to do so as efficiently, and cannot therefore be as flexible as an oscillating propeller.

There are two main reasons in my opinion why the bird is so much more capable a flyer than the present aeroplane can ever hope to be. One is that he has a flexible power plant, and the other is that he is able to do full justice to the flexibility of his power-plant by virtue of the flexibilty of his propeller.

The bird uses an oscillating propeller from necessity, but he could not, in my opinion, have chosen a better propeller had he been given the opportunity.

We are given the opportunity to choose, and I hope I have gone some way to convince you which way the choice should lie.

DISCUSSION

The PRESIDENT: Ladies and Gentlemen, I hope that the extremely interesting and instructive paper which has been read will call forth an equally interesting discussion, and that there will be some gentleman to lead the discussion at once.

Mr. THIERSCH: May I ask for a design of the propeller blade?

Mr. COOPER: It depends on the feathering that one adopts. If we adopt one analogous to that of a bird's wing I should say the most efficient shape would be also analogous to a bird's wing. If one adopts the third feathering there is nothing to go upon except experiment. I am hoping to have some models tested very shortly, and I hope to be able to tell you about the action of the various blades on the air at some future time. At present I am using a blade with that third feathering which is practically square, or, rather, I should say, diamond; I run it from one corner, but it is purely a matter for experience to say which is the best shape.

Mr. PORTER: Mr. President, Gentlemen, Mr. Cooper is to be congratulated very much on the comprehensive way in which he has dealt with the matter. It is a very difficult subject, and to put it into a paper like this one to-night is very clever of him. As regards jet propulsion, I think, as far as the jet is concerned itself, there is not the slightest doubt that one can obtain a very high efficiency indeed, and, as Mr. Cooper says, it is not so much the efficiency of the jet—it is the efficiency of the propeller, and the channel leading to the jet. Where centrifugal fans are used for obtaining a jet, of course, we obtain an increase of static pressure by means of the centrifugal fan. A centrifugal fan is most efficient. When working against a pressure it is generally reckoned to have a

mechanical efficiency of 66 or 70 per cent. based on the consideration of pressure alone. In the experiments that were made some years ago in connection with the propulsion of ships I think there is not the slightest doubt about the fact, in the light of our present knowledge, that the propellers were very badly designed and the pipes leading to the jets were too small. The result was that the general efficiency was very poor. I have no doubt that if the Admiralty were to build a vessel to-day on those lines—jet propulsion—they would get a very much better efficiency than they did 30 or 40 years ago. The efficiency was then very low indeed—in the first vessel I think it was only about 15 per cent. Subsequently I think Messrs. Thornycroft's boat gave about 25 per cent.

Mr. COOPER: Yes, that is so.

Mr. PORTER: As regards the machine I am interested in—which Mr. Cooper was kind enough to mention—and with respect to the stationary thrust, although I have not obtained actually an equivalent thrust to the screw, I have obtained about 35 per cent. efficiency upon the static thrust only—I think in an ordinary screw you get about 50 per cent.—but you see I have only made comparatively few experiments, yet I am quite convinced, as far as the stationary thrust is concerned, that the centrifugal machine would give an equivalent thrust, but that is not the special case where the centrifugal fan would come in. It is my impression—I may be wrong, but it is my impression—that, given a forward motion, the centrifugal propeller machine will prove its value, because, with a forward motion, the resistance to the downward velocity of air from the propeller is greater and the propeller is called upon to create an increased static pressure, and when the propeller is working under pressure it is the ideal condition. As regards the oscillating propeller, I think the diagrams and the description Mr. Cooper gave us are very interesting, and to me in particular, because I must admit I knew next to nothing about it. It seems to me to be a very great pity that it should not be tried as soon as possible. I take it that, although Mr. Cooper has not mentioned the exact method of application, it is in his mind as to the particular way he would use it on a flying machine, that is, the relative position in which it would be placed, etc. In conclusion, I must congratulate Mr. Cooper very much on the character of the paper he has submitted to us.

The PRESIDENT: In according a very hearty vote of thanks to Mr. Cooper for his admirable paper—a most interesting and instructive one—there is, I think I may say, a great deal still to be learnt in propeller efficiency, for we have yet in front of us nearly all the methods adopted by Nature to copy and adopt if they are found to be more useful and effective than the screw propeller. At any rate, in Nature there seems to be no waste, or very little. And I think if the principles —I have studied Nature all my life, and so I am that way inclined—but I think if the principles of natural flight were better observed and studied in the construction of the aeroplane, greater safety and great—even much greater—success might, I think, be looked for. And the much dreaded force of gravity when the engines cease in mid-air, as engines will do sometimes, might be pressed into service as in Nature, and so valuable lives would be saved in the place of the serious accidents we so often hear of. I am quite sure you will all join with me in according a hearty vote of thanks to Mr. Cooper for his most useful paper—I think I may say that it is a paper that I have been looking for, I won't say for how many years, but it is now forty years since I began to study the question myself, and I thank you, Mr. Cooper, on behalf of the Aëronautical Society for your interesting paper. (Loud applause.)

Mr. COOPER: Mr. President, Ladies and Gentlemen, I am very grateful to you for your kind appreciation of my efforts to-night. I hope when I have got the tests out which I mentioned before that they will be of interest to you also. If I have been able to do something towards advancing that ideal which we all have at heart—I think I may say that all of us as members of a Scientific Society have the ideal of the perfection of mechanical flight at heart—if I have been able to do anything to advance that ideal I hope I may not be called upon to discover anything which I could desire more.

PLAN SHAPES OF FLYING MACHINES AND GLIDERS FOR MAXIMUM AUTOMATIC STABILITY AND CONTROL

By A. P. THURSTON, B.Sc.

The automatic stability of a ballasted glider depends upon the travel of the centre of pressure with variations of the angle of inclination. It follows that for maximum automatic stability the *travel of the centre of pressure* on either side of the centre of gravity *must be a maximum* for a minimum alteration in the angle of inclination. It also follows that the moment of inertia of a machine about a lateral axis through the centre of gravity should be a minimum since the effect of inertia would be to oppose the influence of the restoring couple introduced by the travel of the centre of pressure.

The travel of the centre of pressure may be increased in three ways. (1) The first method is by the introduction of a second plane at a distance in front of or behind the main plane and set at an angle. If the front plane is set at a *negative angle* with the back plane, *i.e.*, so that it meets the air at a lesser angle than the back plane, then as the inclination of the machine decreases the front plane will reach a position in which it ceases to lift and, upon a still further decrease in inclination, the air will act upon the top of it and introduce a depressing force. This force will oppose the couple introduced by the travel of the centre of pressure. Conversely it follows that the travel of the centre of pressure may be increased, if the rider plane is at the front, by placing it at a *greater angle* relatively to the air than the main plane, and conversely, if the rider plane is at the *rear*, by setting it at a *less angle* than the main plane.

(2) The second method of increasing the travel of the centre of pressure is by utilising the wash of the front plane. The lifting properties of the air in the "wake" of the front plane are not so good as those of a clear run of air. Thus, if a rear plane is provided its lift would *decrease* as it rises at a greater rate than it would do in a clear run of air, and conversely the lift would *increase* at a greater rate as it falls. This is equivalent to *increasing the range of travel* of the centre of lift, *i.e.*, of increasing the restoring couple. It follows that for maximum stability the rear plane should be placed as far as possible behind the front plane and it should be placed so as to take the *maximum advantage of the shielding effect*.

(3) The third method of increasing the travel of the centre of pressure is by the use of certain shapes or aspects of planes for the front and rear respectively. Now, it follows that the sensitiveness of a machine may be increased by arranging that the lift of the front plane shall *decrease at a less rate* with decrease of inclination than the lift of the back plane. This can be done (*a*) by giving the front plane a *greater length aspect ratio* than the back plane, since the normal pressure on a normal plane is practically independent of the aspect, but, as the inclination is reduced, the normal pressure per unit area is greatest on the plane having the greatest length aspect ratio. (See the experiments of Stanton, Dines, Langley, etc.)

(*b*) By forming the front plane as a *rectangle* and the back plane as a *triangle* with the apex towards the front, since a triangle, with the apex to the front, is the shape in which the lift varies at the greatest rate with inclination. This shape of triangle also has the maximum travel of the centre of pressure.

It can be readily proved that the damping effect on any longitudinal oscillation is greatest when there is the greatest difference in the areas of the two planes (the product area of rider plane × distance from centre of gravity being kept constant).

Now for maximum efficiency in flight the main plane should have the shape and area giving the maximum lift efficiency, *i.e.*, it should be (approximately) a

rectangle in "length aspect." The shape of the main plane being thus fixed we are only able to vary the shape and position of the rider plane for the purposes of increasing the automatic stability. Thus it follows as the result of the previous reasoning that:—

(*a*) If the rider plane is in front it should have a *large aspect ratio* in length aspect and a *long span* approximating to that of the rear plane.

(*b*) If the rider plane is behind it should have a *smaller length aspect ratio* than the front plane and preferably be *triangular* with the apex towards the wind.*

(*c*) In both cases the rider plane should be set *as far as possible* from the main plane, and the planes should be set at *a positive angle* with one another, *i.e.*, the front plane should present a greater angle to the wind than the back plane.

(*d*) The moment of inertia of the machine should be a minimum.

Gliders constructed on these lines have given most satisfactory results even in disturbed air currents.

This subject of best plan shapes is not only a most interesting one, it is also one of the most important at the present time and appears worthy of a full discussion.

MEMBERS' MACHINES

No. II: LIEUTENANT J. W. DUNNE'S BIPLANE

The machine is a biplane of entirely novel design, intended primarily to solve the problem of automatic stability by the shape of the carrying surfaces, and not by any extraneous balancing or controlling device. The salient features of the machine are the backward slope of the planes, which, in plan view form an angle with the apex in the direction of flight, and the absence of a tail or supplementary planes of any description. The following are its chief dimensions: Span 46 ft.; length (fore-and-aft), from apex to rear wing-tip, 20 ft. 4½ ins.; length of body 19 ft.; surface 560 sq. ft.; weight (including pilot and 6 gallons of petrol), 1,700 lbs.; engine, 4-cylinder 50-60 H.P. "Green," 1,100 r.p.m., driving twin propellers placed one on either side of the body in the rear.

The weight in flight being 1,700 lbs., the aeroplane carries a load of about 3 lbs. per sq. ft. The speed in flight averages about 40 m.p.h.

The chord of the surfaces is even throughout—6 ft.; the vertical distance between the surfaces is also constant at 6 ft.; at either extremity a vertical curtain is placed between the surfaces to prevent leakage of air sideways. The surfaces slope back from the apex at an angle of 58° on either side, the rear wing-tips, therefore, actually being in the rear of the aft end of the body, and the entire outer extremities of the wings lying back well behind the centre of gravity.

The curve or camber of the planes is not uniform: briefly, it may be said that each wing may be viewed as a portion of the surface of a cone with the apex to the rear. A consequence of this is that the angle of incidence of each wing gradually decreases from the root to the tip; so much so, that while the angle at the root is positive, that at the tip is distinctly negative, the difference in the respective angles being 45°. Apart from this, an interesting feature is the extreme downward bend of the *trailing* edges over a short distance where the two surfaces meet in the centre; this arrangement has been adopted chiefly to enable the aeroplane to right itself naturally in the event of its having assumed a vertical position in the air. A further interesting consideration is that this machine is

* An interesting confirmation of this reasoning is to be found in the fact that since these conclusions were arrived at the Blériot, Verheyer, Etrich and other monoplanes have been provided with a fan or triangular shaped tail and the front elevator of the Farman machine has been extended.

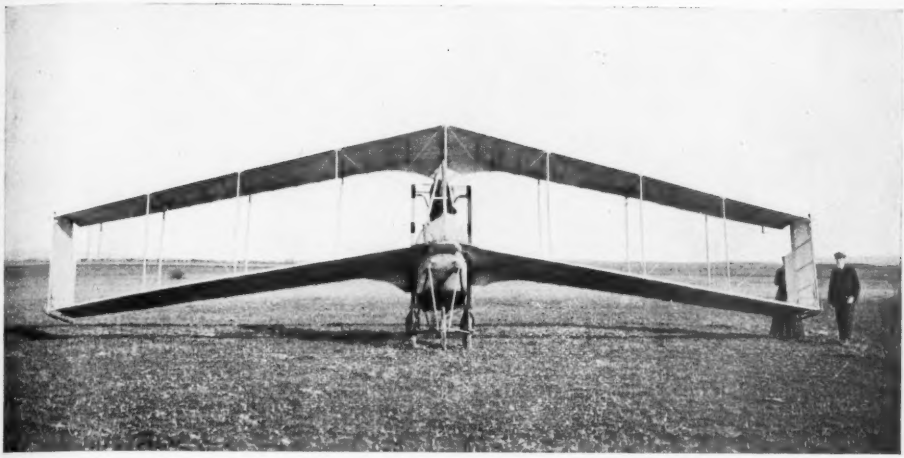
the only one that could safely be forced backwards. It may be added, briefly, that the loss in efficiency arising from the negative angle of the wing-tips is compensated by the backward slope and angle of the surfaces, which naturally causes the flow of air to be deflected outwardly beneath the planes and even induces a certain amount of compression beneath the outer ends.

The body is entirely covered in; the pilot's seat is in the prow; the motor further to the rear. The centre of gravity is well forward, and about 6 inches above the lower plane. The propellers are carried on a transverse girder, and are chain-driven in the same direction—contra-clockwise viewed from the rear. The centre of the boss is situated 1 ft. 2 ins. above the lower plane, and 4 ft. from the central axis of the machine. The propellers, designed by Capt. Carden, are of solid wood, 7 ft. in diam., 7 ft. 6 in. pitch, each weighing 21 lbs.

Lieutenant J. W. Dunne's biplane at Eastchurch
The photograph is partly front and partly side view, but clearly shows the backward slope of the planes

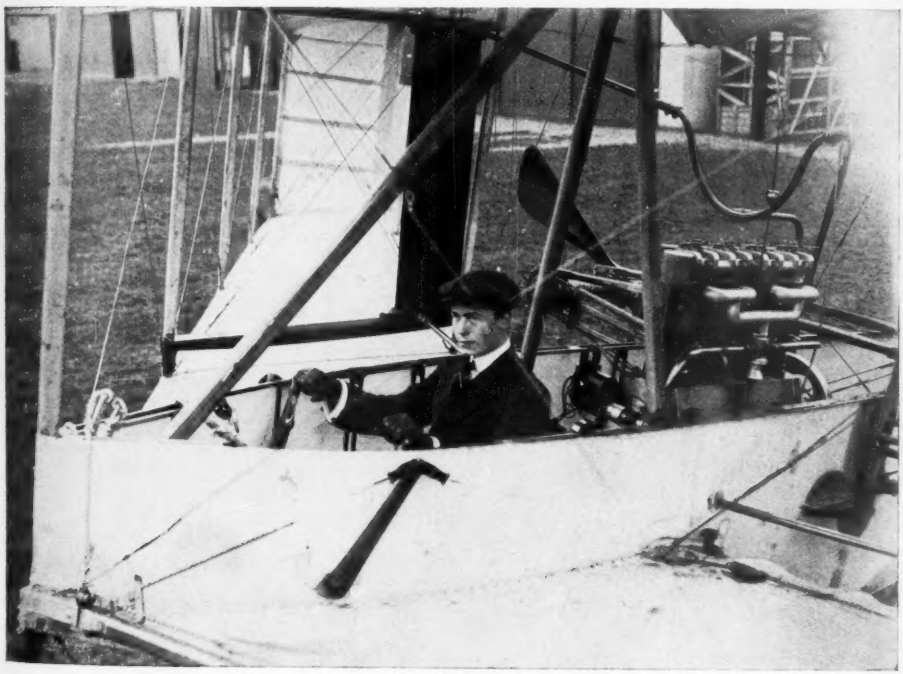
The chassis comprises two main wheels, with a small wheel-and-skid fore and aft. The system of controls is extremely simple. The trailing edge of each extremity of the upper plane forms a hinged flap, measuring 7 ft. 2 ins. by 1 ft. 9 ins. These are independently controlled by two levers, one on either hand of the pilot; a couple of mirrors allow the pilot to ascertain the working of the steering-flaps when in flight. The throttle control is fixed to the right-hand lever.

With regard to the actual performances of the machine it is only necessary to recall Lieut. Dunne's remarkable flight on May 27, at Eastchurch, when the machine covered a distance of close on two miles, absolutely uncontrolled by the pilot, who only manipulated the steering levers in rising from the ground and again when alighting. On this, as on other occasions, the aeroplane displayed a high degree of stability, which affords considerable support to Lieut. Dunne's claim to have achieved automatic stability.



The Dunne Biplane

Front view. The gradually diminishing incidence of the planes towards the tips, and the actual negative angles near the extremities, are well shown, and also the curious downward bend of the planes in the centre. Another point of great interest, which is clearly illustrated, is the *high* centre of gravity



The Dunne Biplane

This photograph shows the interior of the car and controls, and the driving mechanism. The two levers, which work independently, each control one steering-flap. To a crossbar, immediately in front of the pilot, are fixed two small mirrors for observing the action of the steering-flaps. Right in the bows may be noticed the landing tackle, attached to a stake which is driven into the ground to hold down the aeroplane after landing in the open. The photograph fails to indicate the actual extent of the backwards slope of the planes, which amounts to 58° on each side

AIRMANSHIP IN OUR SCHOOLS

By PATRICK Y. ALEXANDER

At a time when demonstrations of flight are daily taking place all the world over it surely cannot be out of place in the Journal of the Aëronautical Society of Great Britain to encourage attention to airmanship in our schools.

There are 15,000 boys at this moment in the British Isles competent to participate in the great development that has occupied the attention of the Society for the last fifty years, and at slight cost the aid of the Board of Education might be asked to advise the authorities of schools and colleges and technical institutions as to the importance of, as well as of the value that may be derived from, theoretical and practical demonstrations.

Scholarships have already been awarded by South Kensington for particular evidence of practical ability to those who have shown talent and resource to continue their work as a practical means of earning their living. Theoretical and practical instruction is quite within the capacity of nearly all our schools and colleges. Short lectures assisted by simple models costing but a few shillings supplemented by lantern slides of actual machines do much to help the imagination of the boys, and if this is continued by outdoor work with summer camps, models, gliders, and visits to aviation meetings the ground will be prepared for a very excellent appreciation of the elements of aerial navigation.

Farmers and landowners generally could do much to assist and at the same time benefit themselves financially by allowing camps for short periods on their property, and, of course, under the authority of competent and responsible instructors.

Materials for models, even large ones, are easily procurable and not expensive, and such vast funds of enjoyment and instruction can be derived from flying models or even if funds can be arranged for the construction of a glider that every boy could have the experience of power flight.

It has been patent to experts for many years that 100 sq. ft. suitably disposed is sufficient to carry a boy when travelling at 20 miles an hour, and this can be achieved by a tractive pull of 30 lbs., which can be obtained from an adaptation of cycle motors. Such an aeroplane and motor would probably cost about £30.

There is a great deal being published in many excellent weekly and monthly periodicals containing a vast fund of information, and this is being done at an unremunerative return which could be made to pay by the support of our young budding aeronauts. The weekly papers especially contain practical and valuable reports of aviation meetings not only in the country but abroad, and many boys abroad would be glad to correspond with their fellow workers in this country.

It is premature to arrange a curriculum for schools, but the advent of aerial machines has been so rapid that many parents are really wondering whether boys may become practical aviators or constructors as a profession. Certainly the prospects of all boys will be materially improved by a sound knowledge of the science and practice of airmanship.

SUGGESTIONS FOR A FLYING MACHINE

By EMANUEL SWEDENBORG

[*Even the bare fact that Emanuel Swedenborg designed a flying machine, relying in part on the principle of the aeroplane, is not generally known. Writing from Rostock to his brother-in-law Benzelius, on September 8, 1714, Swedenborg—then a young man of twenty-six years—mentioned fourteen mechanical inventions which he had then recently completed; among these is cited "a Flying Vehicle, or the Possibility of being sustained in the air, and being conveyed through it." The manuscript embodying this invention, together with the drawing here reproduced, was sent to Benzelius a few months later and is preserved in the Cathedral Library at Linkoping in Sweden. Soon after his return to Sweden in 1715, Swedenborg undertook the publication of a journal devoted to physics and mechanics, entitled* Dædalus Hyperboreus, *in the fourth number of which, published in 1717, appeared the account reprinted below under the designation of "The published account." There is no need to enlarge on the merits of Swedenborg's invention, which, incidentally, it should be noted is described merely as "a suggestion"; it will be obvious, at any rate, that it is the first rational proposal for a flying machine of the aeroplane type, as opposed to the "lighter-than-air" vessel invented by Francesco Lana some fifty years earlier and somewhat scornfully rejected by Swedenborg. We are indebted for the following translation—by Hugo Lj. Odhner and Carl Th. Odhner—to the pamphlet published by the Swedenborg Scientific Association of Philadelphia, a copy of which has been kindly lent us by the Reverend James R. Rendell, of Accrington.*]

I.

THE MANUSCRIPT

DESCRIPTION OF A DÆDALIAN OR FLYING MACHINE

1. Make a square box, or car, t t t t, of lightest possible material, such as leather, cork, or, best of all, birch bark, with thin wooden splints, the whole, however, strong enough to hold a man without danger. The box should be 2 ells [yards] in length and 3 in width, for the wings are to be moved sideways and the box, therefore, should be greater in width than in length; the depth should be 1 ell, with space within for a Dædalus or aviator.

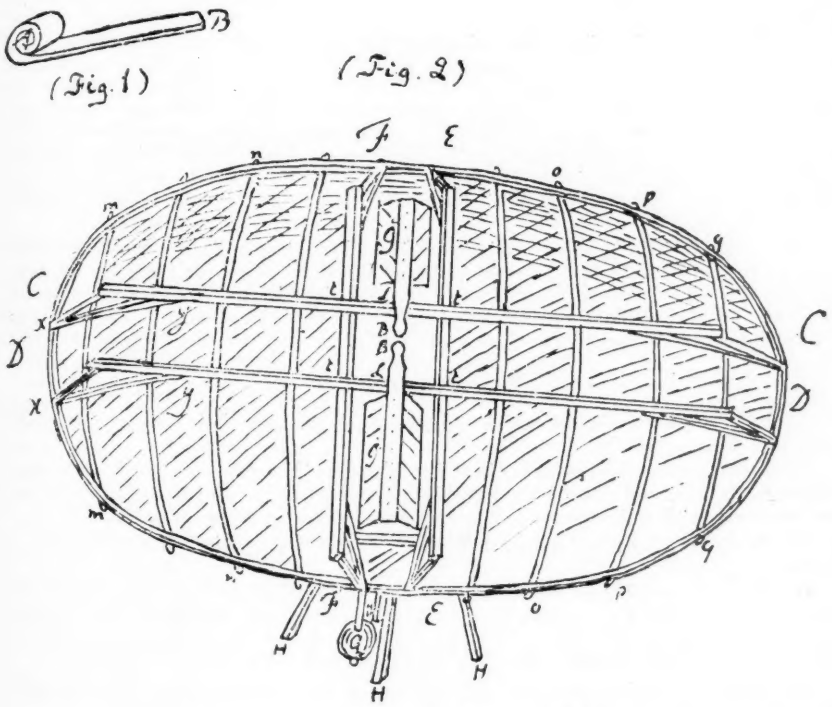
2. A sail should be stretched as wide as possible and be bent into a hollow; examine it carefully to make sure there is no rift or crack in the sail for the air to pass through, for the pressure of the atmosphere will be so strong that if there be any rift, the air will be forced through with a whistling noise. The sail should be 150 square ells; for since an eagle or glead occupies about 2 square feet of surface when it lies still in the air, with tail, body, and all, therefore, as our flying machine with all its gear will be about 300 times heavier than an eagle, it must also occupy a space 300 times greater than an eagle in relation to its weight, that is to say, 150 cubic [square?] ells.

The sail may be made in the form of a square, oblong, circle, just as you please; best, perhaps, would be an oval form, provided with a support.

3. The sail is fastened and bent as may be seen from the drawing (Fig. 2), viz., there are 4 poles lengthwise and crosswise, CC, DD, EE, FF, all of which are bent at the ends, at yx, yx. Then make a thin wooden rim round it, D C m n F, bent into an oval shape. To this rim are fastened the splints, m m, n n, o o, which are also bent, and underneath all this the sail is securely fastened.

4. The two wings, j j, are placed between the sails, and they also should be bent into a hollow, in order to catch and keep the air better at the downward stroke than at the upward. It would do no harm if they were tilted obliquely backwards, like the arms of a windmill. They may be made of splints covered with sail-cloth, so fastened to the splints above that it opens a little at the upward stroke, for the air to press through.

5. L L is the true centre of the machine, where it lies in a balance. The wings must also be balanced, so that B B on the one side is equal in weight with J J on the other. The wings should be as light as possible, but the most important thing in connection with them is a spiral spring (*sling-fjader*), placed lengthwise beneath each, shaped as in Fig. 1.



This spring is fastened to the car in such a manner that A B runs lengthwise along the wing, while A is fastened to the car itself. Now when the wing moves upwards, A B moves against the spiral in the spring, so that the spiral circle in A is rolled up, but at the downward stroke it recoils and carries the wing downward with force.

6. H H H H are four poles proceeding downwards, *i.e.*, four legs; it would do no harm if they were provided with rollers for the machine to stand upon.

G is a weight or beam [*vectis*], which is to keep the machine in a horizontal position, so that it may not tip over.

Requisites for the building of the machine: (1) The position of the poles and the splints may be seen from the drawing. (2) The seat is within the basket, and beneath there ought to be a bar under which the weight should be fastened. (3) The centre of gravity, or the balance, should be determined in the middle of the car—the machine should be placed between two poles and hung on two axles, from which it may be seen where the wings and the weight are to be fastened.

Requisites as to the Weight.—The weight of the whole machine ought not to be more than 20 Lispund,* or 1 Skeppund, viz., the man or Dædalus, 8 Lp.; the sails 150 or 160 square ells—2½ Lp.; the car itself 1½ Lp.; the framework 5 Lp.; the weight G, 1 Lp.; the wings, with the springs, 2 Lp.; the rest 1 Lp. Altogether, 21 Lp.

Requisites as to the Size.—The sails may be expanded in whatever form you please, to the size of 150 or 160 square ells. If the form is circular, then a diameter of 14 ells would be sufficient; if oval, then the larger diameter might be 16 ells, and the shorter 12; if square, then the side would be 12½ ells. If oblong, the longer sides ought to be 15, the diagonal 10 ells; all these dimensions would occupy a space of 150 or 160 square ells. (2) The car should be 2 ells long, 3 broad, and 1 deep. (3) The wings 2½ ells long and ¾ broad. (4) The weight or beam should be almost 4 ells from the bottom, when it would be able to keep in balance several Skeppund.

Obs.—The springs below the wings ought to be strong and should weigh about 5 or 6 Lp. (2) Where the sails are fastened [?] they ought to be bent inward. (3) The Dædalus himself should determine the flight by his swaying downwards, upwards, or to the side. (4) One must see if any [additional] sail be necessary to direct the course, downwards or perpendicularly.

Proofs

(1) From eagles or gleads, which are able to lie still on their wings or on their expanse, or sway in the air.

(2) From paper-kites, which often in calm weather are able to keep themselves in the air, and rise higher and higher up by only a slight motion, and yet not tip over, although surrounded by wood and other heavy materials.

(3) That Kirchberg and others tell about such things, although nothing [——] is seen expanded.

(4) That the wind can lift up very heavy materials, so that when it blows against a gate with force it can blow it open even though two men be pushing against it when yet it is often 16 square ells in extent. How, then, would it act on a surface of 150 square ells, with the wings helping along?

(5) A student with a side-cape fell unharmed down from Skara church tower in a strong wind.

(6) A kite, the higher it reaches, the less motion is needed to keep it in the air, as is apparent; while down by the ground it has to be lifted up by motion.

Observata

A machine such as this can be made to go when there is a strong wind; otherwise it will remain still.

It may be drawn forward on the rollers, where the ground is even. Or it may be pushed down from a roof, after it has been weighted with ballast, to the weight of a man.

* The old Swedish "Lispund" = 18 lb. 12 oz. The "Skeppund" = 374 lb. or 171 kilogr.

II.

THE PUBLISHED ACCOUNT

SUGGESTIONS FOR A MACHINE TO FLY IN THE AIR

From the thought of Assessor Polheim [in a preceding article on "Rational Duplicates in Perpendicular Falls"] we may figure out the power and resistance of the air to all objects, expanded as well as compact or compressed. From this, as also from the flight of birds, it would be easy to come to the conclusion that a machine might be invented which would carry and transmit us through the air, and that we are not to be excluded from the element overhead, even though no other wings be given us than those of the understanding. Those who before now have given thought to such a work of Dædalus or Mercury have set before them an impracticable principle, and have founded their notions on things contrary to our atmosphere, viz., great balls which, by being emptied of air, acquire a sufficient lightness to raise up a machine and its Icarus as well.

But if we follow living Nature, examining the proportions that the wing of a bird holds to its body, a similar mechanism might be invented, which would give us hope to be able to follow the bird in the air. First, let a car or boat or some like object be made of light material such as cork or birch bark, with a room within for the operator. Second, in front as well as behind, or all around, set a widely stretched sail parallel to the machine, forming within a hollow or bend, which could be reefed like the sails of a ship. Third, place wings on the sides, to be worked up and down by a spiral spring, these wings also to be hollow below in order to increase the force and velocity, take in the air and make the resistance as great as may be required. These, too, should be made of light material and of sufficient size; they should be in the shape of bird's-wings, or the arms of a windmill or some such shape, and be tilted obliquely upwards and be made so as to collapse on the upward stroke and expand on the downward. Fourth, place a balance or beam [*vectis*] below, hanging down perpendicularly to some distance and with a small weight attached to the end, pendent exactly in line with the centre of gravity—the longer this beam is, the lighter it must be, for it must have the same proportion as the well-known [Roman] *vectis* or steelyard. This would serve to restore the balance of the machine whenever it should lean over to any of the four sides. Fifth, the wings would, perhaps, have greater force, so as to increase the resistance and make the flight easier, if a hood or shield were placed above them, as is the case with certain insects. Sixth, when now the sails are expanded so as to occupy a great surface and much air, with a balance keeping them horizontal, only a small force would be needed to move the machine back and forth in a circle, and up and down. And after it has gained [sufficient] momentum to move slowly upwards, a slight movement and an even bearing would keep it balanced in the air and would determine its direction at will.

It seems easier, however, to talk of such a machine than to put it into actuality and get it up into the air, for it requires greater force and less weight than exists in the human body. However, there are three or four requisites that would be of chief assistance: (1) a strong wind, which has a considerable effect on similar objects, for in calm weather it would be better to keep quietly and humbly by the ground; (2) the machine should be pushed off from a considerable elevation, for the primary difficulty will be to force oneself up from the level; much would be gained toward this end if the machine were lifted up some distance into the air by means of ropes; this would do as much as a strong puff of wind; (3) the size and width of the sails (as well as the force of the wings) ought to be in proportion to the weight, and must increase with the weight in the ratio of 3 to 2, as Assessor Polheim shows in the article; (4) in order to acquire a downward force in the wings sufficient for moderately calm weather the science of mechanics might, perhaps, suggest a means, viz., a strong and stiff spiral spring, which, when set free, would have the power of three or four persons; and it

could be bent upward, though somewhat more slowly, by a light and quick mechanism.

If these advantages and requisites are observed, perhaps in time to come someone might know how better to utilise our sketch and cause some addition to be made, so as to accomplish that which we can only suggest. Yet there are sufficient proofs and examples from Nature that such flight can take place without danger; such as birds, eagles and gleads, which, as it were, swim in the air and with all their weight rest on their wings without moving the least feather for several minutes. In the case of kites, made of paper and wood, we see a similar property, in that they keep themselves up in the air without sinking down in the least. It is also well known that a man in Strangnas accidentally fell down from a tower in a strong wind, but the cape which he wore so far saved him that he came to the ground unharmed. And there are other cases which may be considered; although when the first trials are to be made you may have to pay for the experience and must not mind an arm or a leg.

The ingenious Fontenelle writes humorously about such a machine, saying: "The art of flying is as yet hardly born. It will be perfected and some day people will fly up to the moon. Do we pretend to have discovered everything, or to have brought our knowledge to a point where nothing can be added to it? Oh, for mercy's sake, let us agree that there is still something to do for the ages to come!" (*Entret. sur la Pluralité des Mondes*, pp. 51, 52.)

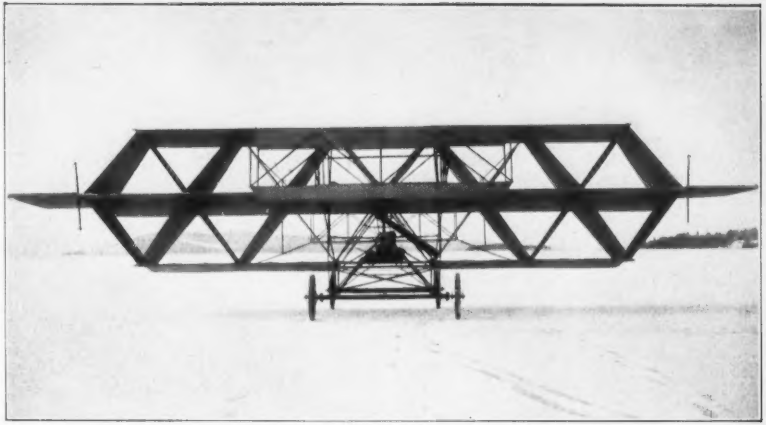
The learned Assessor Polheim pronounces a more doubtful opinion, as follows: "As to artificial flying it probably has the same difficulties as the artificial production of gold or perpetual motion, etc., although at first sight it seems no less practicable than desirable; but when we examine the matter more closely we meet something which Nature seems to deny us; as in the present case that all machines do not retain equal proportions in great dimensions as in small, even though all the parts be made the same and in the same proportion; for instance, although a cane or stick may be capable of carrying not only itself but also some weight in addition, yet this does not apply to all dimensions, even if the length and thickness keep the same proportions, for when the weight increases in triplicate ratio the force increases only in duplicate; it is the same as to surfaces. Whence it happens that great bodies cannot support their own weight. And since Nature itself demands of birds not only a very light and strong material for feathers, but also wholly different tendons and bones in the body itself, which tend to strength and lightness, and which do not exist in other bodies; therefore, on account of the lack of necessary materials it is much more difficult to accomplish that effect in the air which is needed for the realisation of this thing, in case a human body is to accompany the machine. But if it were possible for one person to move and direct all that pertains to a machine sufficiently large to be able to carry him, then the point would be gained. However, it would be well to take advantage of a wind, if the same were constant and invariable."

But enough this time about our Dædalus.

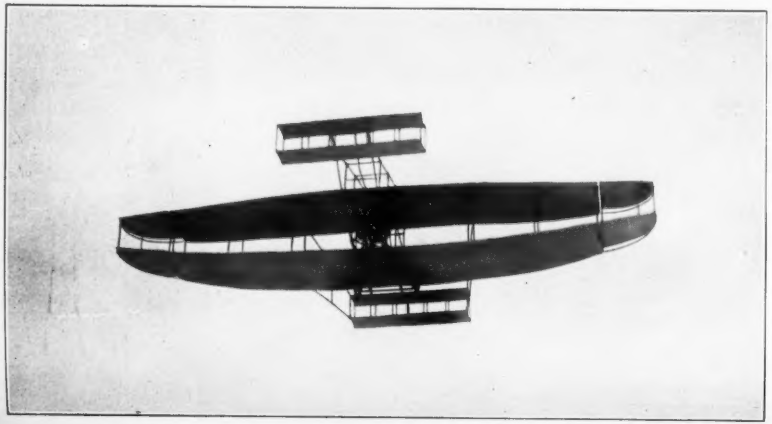
NOTES

The Canadian Aerodrome Company—At Baddeck, in Nova Scotia, Messrs. Baldwin and McCurdy, assisted by the advice of Professor Graham Bell, have for some time past been manufacturing and experimenting with flying machines, and have accomplished some splendid work. It is to be hoped that they will visit Europe next year and give some ocular demonstration of their achievements; in the meanwhile the following account and illustrations of their machines will be found interesting. It will be noted that the "Baddeck" type of aeroplane has an aggregate of considerably over a thousand miles of flight to its credit.

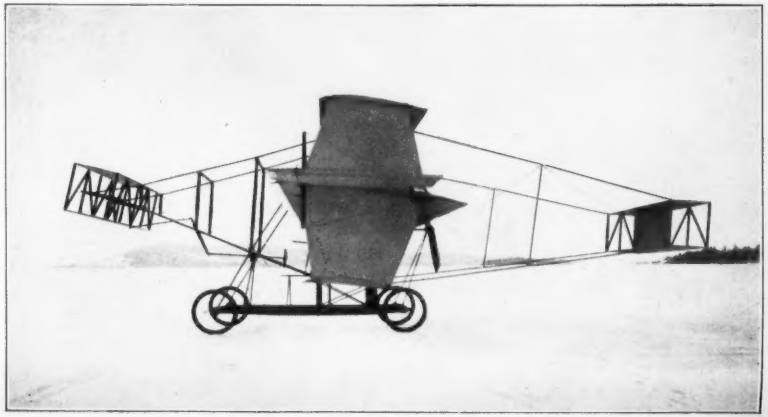
"Baddeck No. 2."



"Olonos No. 1."

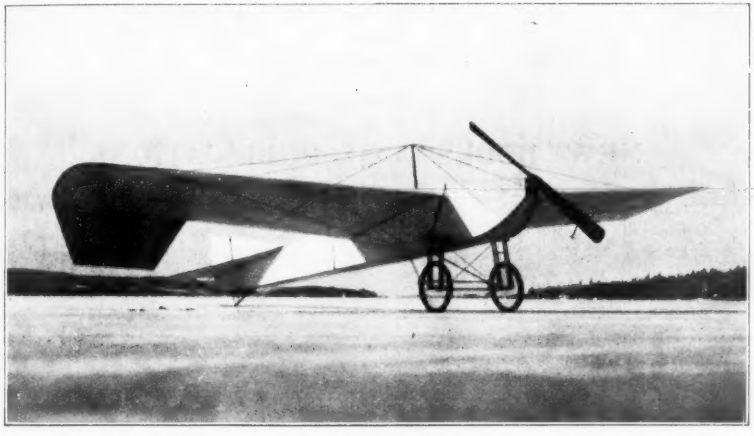


"Baddeck No. 2."



"Olonos No. 1."

"Baddeck No. 2" is similar to "Baddeck No. 1," with the exception of the lateral control planes, which in the latter are placed between the main planes. A wheel control operates the front elevator and the rudder and also carries the engine throttle. Lateral control is effected as in the Curtiss biplane by movements of the pilot's shoulders operating the wing-tips (which are true planes and not curves) by means of a yoke. The 7 ft. 6 in. propeller, with a pitch of 9 ft., is of British Columbia fir, and is driven by a 6-cylinder, water cooled, 40-h.p. gasolene Kirkham engine, weighing 320 lbs. The dimensions of the aeroplane are as follows:—Span, 49 ft. 4 ins; span, exclusive of wing-tips, 39 ft. 4 ins.; total fore-aft dimension, 33 ft.; depth of main planes, 7 ft.; gap at centre, 6 ft. 3 ins.; gap at ends, 3 ft.; elevator planes, 12 ft. span, 2 ft, depth, 30 ins. gap; fixed tail planes, 12 ft., span, 28 ins., depth, 30 ins. gap. Distance between front edge of elevator and front edge of main planes, 15 ft.; distance between rear edge of tail planes and rear edge of main planes, 11 ft. Total weight with pilot, 1,200 lbs.; total supporting surface, 600 sq. ft.



"Mike" Monoplane

The material used is spruce covered with the fine duck known as "racing cloth." The cloth is laced over the front edge of the plane, which edge is then covered with sheet aluminium, thus making a smooth surface.

The "Oionos No. 1," of which no dimensions are available, has not yet been tried with a sufficiently powerful motor. It is a development of Dr. Graham Bell's tetrahedral kites, and should prove a slow but exceedingly stable machine.

The "Mike" monoplane is the first built by the Company for Mr. G. G. Hubbard, of Boston, who has made several successful flights with it. Span 34 ft.; fore-aft dimension, 32 ft. Similar engine to the "Baddeck No. 2."

We are indebted to the courtesy of Major G. S. Maunsell, Director of Engineer Services, Canada, for permission to use the illustrations and for some of the information in this note, also to the Editor of the *Royal Engineers' Journal* for the kind loan of the blocks.

The First Aeronautical Exhibition, June 25-August 5, 1868 — The accompanying Plate is reproduced from an engraving in the *Illustrated Times*, July 4, 1868, and depicts the Aëronautical Society's first exhibition at the Crystal Palace, which was also the first of its kind held in any country.

The energetic figure in the left foreground with its back to the spectator is that of John Stringfellow, whose model triplane hangs about him. In the Annual Report of the Society for the year the following particulars are given:—"No. 37.—J. Stringfellow, a model; impelled by twin screws worked by steam. This ran upon a wire stretched across the transept. It was seen by several that after a certain velocity had been attained, the machine left the support of the wire and rose up. On one occasion the wire broke just after the start, but the buoyant power of the planes caused so light a descent that

no damage occurred. The model was remarkable for the elegance and neatness of its construction, and was the first experiment adopting the proposed system of superposed aeroplanes to a steam flying machine."

In the right-hand corner is the hull of a similar model; above it is a dirigible exhibited by Francois Heron, and the strange object on the table is J. Kaufmann's aeromotive machine. "The main portion of the weight of this machine was to be sustained by superposed aeroplanes, and the propulsion to be effected by two long wings, which, during the down stroke, were set at an inclined direction backwards, and caused to turn at a forward angle during the up-stroke."

Leaning against the wall on the left is a device exhibited by Mr. W. Gibson, consisting of two pairs of wings. "worked by the feet and arms together, during which action the shafts of the wings swivelled in their sockets so as to give a feathering movement similar to that observed during the flight of a bird."

We are indebted to Mr. C. H. Alderson for the kind loan of a copy of the engraving.

NEW BOOKS AND PUBLICATIONS

*Aeronautical Classics: No. 3.—The Art of Flying. Thomas Walker. London: Aëronautical Society of Great Britain. 1910. 1s. n.

Aeronautical Engineering. H. S. Hele-Shaw. Reprinted from the Trans. Liverpool Eng. Soc. Liverpool: G. Reed, 1910. pp. 135-165

*Ballons et Aéroplanes. G. Besançon. Paris: Garnier Frères, 1910. pp. 346. 3.50 francs

*Bibliography of Aeronautics. P. Brockett. Washington: Smithsonian Institution, 1910, (London: W. Wesley). pp. 940. 8s. 6d. n.

C.P.I.A. Procès-Verbaux, Rapports et Mémoires du IVe Congrès International d'Aéronautique à Nancy, 18-23. Sept. 1909. Paris: Dunod et Pinat, 1909. pp. 473

Der Vogelflug als Grundlage der Fliegekunst. Otto Lilienthal. 2nd edition. Berlin: Oldenbourg, 1910. pp. 186. 9 marks.

*Dictionnaire Illustré de la Navigation Aérienne. F. de Baeder et G. Debouchet. Paris: Librairie Aéronautique, 1910. pp. 138. 3 francs

Epitome of the Aeronautical Annual, Nos. 1, 2 and 3. Edited by Jas. Means. Boston, U.S.A.: W. B. Clarke, 1910. $1 n.

*Flight Manual. A. E. Berriman. London: St. Martin's Pub. Co. pp. 279. 10s. 6d. n.

L'Aéroplane de l'Avenir. Henri Picq. Paris: Librairie Aéronautique, 1910. pp. 19. 1.50 francs. (Advocates an improved system of paddle-wheel propellers)

*L'Aviation. P. Painlevé & E. Borel. Paris: F. Alcon, 1910. pp. 266. 3.50 francs

Le Constructeur de Petits Aéroplanes. R. Petit. Paris: Librairie Aéronautique, 1909. pp. 16+3 plans. 1st series. 1.50 francs

Leonardo da Vinci: Conferenze Fiorentine. Milano: Fratelli Treves, 1910. 2nd edition. 10s. n.

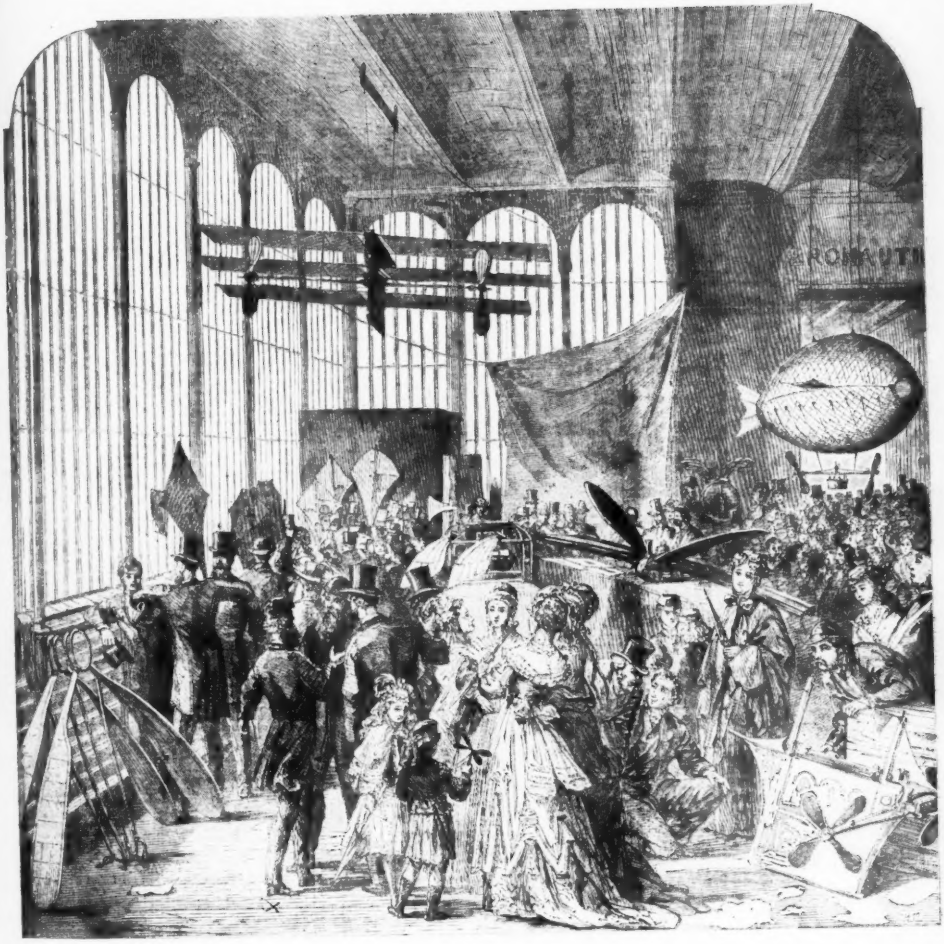
*Model Balloons and Flying Machines. J. H. Alexander. London: Crosby Lockwood, 1910 pp. 127. 3s. 6d. n.

Stabilité des Aéroplanes—Surface Métacentrique. M. Brillouin. Paris: Dunod et Pinat. 1910. pp. 77. 3 francs

*The Art of Aviation. R. W. A. Brewer. London: Crosby Lockwood, 1910. pp. 266. 10s. 6d. n.

The Mechanics of the Earth's Atmosphere. A Collection of Translations. Cleveland Abbe. Washington: Smithsonian Institution, 1910. pp. 617.

* Notice of this book will be found in the present number



THE FIRST EXHIBITION OF THE AËRONAUTICAL SOCIETY OF GREAT BRITAIN

Crystal Palace, June 25-Aug. 5, 1868

REVIEWS

Flight Manual; a Reference Book of Notes, Formulæ and Tables. By A. E. Berriman, Technical Editor of *Flight* (London: *Flight* Office, 44, St. Martin's Lane, 1910; pp. 279; 10s. 6d. net.)

This pocket-book contains a great deal of information useful to the aeronautical student, and will no doubt later on become quite a standard work for those interested in this important subject. It is, of course, at present very difficult to provide a good work of this description as the aeronautical matter, on which its success really depends, is so scattered about through books, journals, pamphlets, etc., that its collection and presentation in suitable form is a very arduous task. A good start has, however, been made and no doubt future editions will improve considerably upon the present one.

The general arrangement of the contents is very good, as the notes, formulæ, and tables are kept separate, and any information required can be easily found.

The book commences with a "Tree of Flight," and a short historical biography. These are fairly complete, but there are in the biography some important omissions. No mention is made of Brearey, the first Hon. Secretary of the Aëronautical Society of Great Britain, whose wave-action model with pectoral cord, was one of the most important discoveries in aeronautics, while Hargrave is only alluded to as the inventor of the box-kite, his far more important work in other directions being entirely ignored. Again, no information regarding Mouillard, Drzewiecki, Eiffel, Goupil, or Kress is given, although all of these men have done aeronautical work of the greatest importance.

The account of "Early Machines" is good, though, of course, brief. Surely, however, the absurd title of "Nulli Secundus" for Dirigible No. 1 of the British Army should not appear in a work like this, especially as this ridiculous name (given, it is said, by an enthusiastic, if not very discreet, newspaper reporter) was, of course, never acknowledged by the Military Balloon authorities.

The "Early Records" are fairly complete, but some information regarding Chas. Spencer's gliding flights (see Proceedings of the Aëronautical Society of Great Britain) might have been given, as also some details of Lilienthal's work. The author of this review saw Mr. Lilienthal make some magnificent glides in 1894, and his brother, who is still alive, could no doubt give interesting information about the numerous flights carried out by these two enthusiastic aeronauts.

The "Notes" contain a great deal of generally useful information regarding motors, fuel, materials, etc., and more purely aeronautical details taken chiefly from Mr. Lanchester's books. As regards the latter, it would be as well to point out that the information given is often only applicable to the particular cases mentioned in the books, and that it should not be used indiscriminately. For example, Notes 37, 39 and 40 ("Least Resistance, etc.") are only true when (as Lanchester states) the aerodynamical resistance varies as the sine of the angle of inclination of the surface; when, as in the case of many arched surfaces, the resistance varies according to a quite different law, these notes do not necessarily hold good, and their use for calculating speeds, etc., would give very unsatisfactory results.

The statement regarding Skin Friction, that "there is every reason to suppose that Langley was not justified in his contention that skin friction was negligible," is, to say the least of it, open to question. No really satisfactory experiments on this subject have ever been made, as most of the experimenters have undoubtedly mixed up the skin friction with the resistance due to the bad shapes of the surfaces, etc., used, and until some really reliable data are available, it is impossible to say whether skin friction is an important item of the resistance or not.

A fair amount of useful information is given about the flight of birds, but the very important rule giving the ratio of surface to weight,

$$\frac{S^{\frac{1}{2}}}{W^{\frac{1}{3}}} = \text{a constant},$$

is omitted.

The statement regarding the efficiency of wings and screws will hardly be accepted by those who have studied this subject: the evidence seems to show that while the maximum efficiency of each is equal, the practically attainable efficiency of the wings is somewhat greater than that of the ordinary screw. As regards the gyroscope and its use for increasing stability, the danger of applying this apparatus to flying machines should be pointed

out; the results hitherto obtained in sea-ships having been, to put it mildly, unsatisfactory. Stability is really a question of design, and gyroscopes, balancers, etc., are quite unnecessary, if the design of a machine is properly worked out.

The Formulæ F. (1-120) are of the usual kind, and cover most of the requirements of aeronauts. Some information regarding the tractive force required on grass might be given with advantage, as at most flying meetings the starting track is of turf, and the extra power required in such cases is considerable.

The Tables (1-179) contain a great deal of very useful information. T. 169 (Birds), however, requires thorough revision; details regarding muscular strength, wing areas, weights, velocities, etc., are now available, and should be included in a table of this description. Birds are far the best fliers at present, and information concerning them is of great importance. As regards T. 160, taken from Lilienthal ("Der Vogelflug," Pl. VI.), it should be pointed out that the results are entirely unreliable. The measurements were made in the wind; a very unsatisfactory way of testing surfaces, and quite independent of this, the velocities were calculated from the formula

$$P_{90} = \cdot 13\ S\ V^2 \text{ (metres and kilogrammes)}$$

which gives the values of P_{90} some 20 per cent. too high. This is a matter of great importance, as not only are the pressures too high, but the gliding angles (or ratio of lift to drift) are also much too small. The only really reliable experiments made by Lilienthal are the ones measured in still air (see Tables II., III., and IV.), and a reference to Table IV. shows how great the difference is.

Table 74 (H.P. of Motors). The rule given by the author of this review (see *Autocar*, January 19, 1907) seems to be simpler than the ones mentioned, and is much easier to recollect.

$$H\,P = \frac{D^2\,S\,N}{11}$$

In the case calculated this gives 29.1 H.P., or about the same value as those given by the O'Gorman, Lanchester, and S. M. M. T. formulæ.

One excellent feature of the book is the diagrams and drawings of machines. These are clear and simple, and will be found very useful. It is to be hoped that a drawing of the Weiss machine will be included in later editions, as this is a very original and carefully designed type.

J. D. FULLERTON, Col., R.E. (Ret.)

Dictionnaire Illustré de la Navigation Aérienne. Par F. De Baeder et G. Dubouchet. (Paris: Librairie Aéronautique, 1910; pp. 138; 3 francs.)

This is a useful little manual for students of aeronautics, who, of necessity, read many French books which contain technical terms that rarely form part of an Englishman's knowledge of the French language. It does not contain any contributions towards an aeronautical vocabulary in English; and in the case of certain difficult terms any attempt to give an exact rendering of the French expressions in English would only end in failure or confusion. So that it is not from this point of view that the volume is useful. Some of the references are interesting. For instance, "Aviateur" is given as meaning generally the pilot of a machine, but used sometimes to denote the machine itself. At a casual glance one finds many words which may come into use unchanged in this country, as "Fuselage," and possibly "Gauchissement." The verb "Planer"—to plane—seems to be an excellent alternative for the English "to glide." And "Gouvernail de direction" and "Gouvernail de profondeur" are two French expressions which suggest that we might adopt the word "governor" to denote either the elevating plane or the rudder. The bibliography given is very incomplete, there being no mention of Lanchester and Maxim, and even "Astra Castra" is omitted.

C. C. T.

Ballons et Aéroplanes. By G. Besançon. (Paris: Garnier, 1910; pp. 346; 3.50 francs.)

The Secretary of the Aéro-Club de France is to be felicitated on the production of thoroughly sound, simply-written, popular history. The book is divided into two parts, one devoted to balloons and dirigibles, and the other to aeroplanes, and there are plenty of excellent illustrations. Though written from a thoroughly French point of view, the book is singularly unbiassed and temperate in tone. We strongly recommend it to schoolmasters as a very suitable French reader.

Hilfsbuch fur den Luftschiff-und Flugmaschinenbau. (Manual for the Construction of Airships and Flying Machines.) By Dr. R. Wegner von Dallwitz. (Rostock: Volckmann, 1910. pp. 351. 9 marks.)

It is significant for the rapidity of development now exhibited by the new industry that a technical book which was published barely twelve months ago should already appear in its third edition, and not only as a reprint, but increased in bulk to more than twice its original compass.

The present edition is essentially a book for the "practical" man, and only touches briefly upon the theory of aeroplanes and stability, sufficiently, however, to bring into prominence those essential points which it is necessary to know for the builder of airships, dirigibles, and aeroplanes, in addition to the ordinary engineering problems connected with their design.

The work is naturally divided into two sections, of which the first embraces some one hundred odd pages and deals exhaustively with the various types of balloons and dirigibles, the power requisite to engine them, their dynamic dimensions, calculation of air resistance, etc.

Useful tables are given regarding the available materials for the outer cover, and in a further portion of the book the various methods of producing and storing hydrogen is fully gone into.

The "heavier than air" flying machine is dealt with in the 13 subsequent chapters, and gives a clear exposition of gliding flight, passing on to the design of the biplane and monoplane, as represented by the leading types, and discusses the materials most suitable for the construction of such machines, their mechanical qualities, methods of jointing, method of calculating sections and girders, etc.

A chapter is devoted to the calculation of the necessary size of motors and a detailed description of the leading motor constructions.

The various propellers, including tables of dimensions and prices, are also extensively dealt with as well as the calculation of their efficiency, both theoretical and practical.

The illustrations are numerous and clear, and altogether the book should appeal very strongly to those who wish to occupy themselves practically with this new branch of engineering.

The author is of opinion that the construction of aeroplanes, at any rate, will eventually be undertaken by carriage builders, to whose present work it most closely approaches.

He strongly advocates the more general practice of gliding to the prospective aviator, and even goes so far as to express the opinion that it will not be very long before such gliding will be included in the ordinary curriculum of our schools in the same way as gymnastics.

A. W. I.

The Art of Aviation: A Handbook upon Aeroplanes and their Engines, with Notes upon Propellers. By R. W. A. Brewer, Assoc.M.Inst.C.E., M.I.M.E., etc. (London: Crosby Lockwood and Son, 1910; 10s. 6d. net.)

Mr. Brewer is to be congratulated on having written a most admirable book; although intended, as stated in his preface, to deal more with the practical rather than with the theoretical aspect of flying machines, it nevertheless comprises a great deal which will be of assistance to every aeroplane designer.

Unlike so much of the air-literature which has been published during the past year or two, "The Art of Aviation" is marked by the author's sound method of treatment and the matter-of-fact manner in which the subject is presented, and especially is this noticeable in the explanation of current aeronautical terms, the difficulties of learners, the manipulation of the various controls, and the concise descriptions of different types of machines, and their constructional details. To the aeronautical expert Chapters VII. and VIII., dealing with the theory and practical efficiency of propellers, will doubtless be found of much interest and value; in the treatment of this somewhat complicated and often controversial subject, Mr. Brewer has been aided by the suggestions and criticisms of Mr. T. W. K. Clarke, who has probably made deeper researches into this problem than anyone in this country, and who is known to have done so much work in deducing the fundamental conditions of maximum efficiency, and also in establishing the relation which exists between the static and moving thrusts of aeroplane propellers.

The book is excellently printed and illustrated; at the end are included some useful tables and plate drawings. The glossary of terms is particularly good. Mr. Brewer appears to be an enthusiastic advocate of gliding flight as the stepping-stone to aviation, and some very clear photographs of Mr. A. Ogilvie's experiments on his Wright-Clarke glider are interspersed throughout the book.

Much criticism would be invidious; it may, however, be suggested that several of the authorities quoted are scarcely those on whose work much reliance can be placed.

In some few instances the author's own arguments appear inconclusive, as, for example, on page 224, where he does not seem to have quite a clear understanding as to the relative pressure intensities required to be borne by front and rear surfaces in order to ensure automatic longitudinal stability.

It is, however, not too much to say that this is one of those books which should be studied by everyone interested in aeronautical science.

H. F. L.

L'Aviation. By Paul Painlevé and Emile Borel. (Paris: Alcan, 1910; pp. 266; 3.50 francs.)

As an elementary text-book of the science, "L'Aviation" will not easily be surpassed, and students looking for a reliable guide to the science of flight cannot do better than procure it. The principal contents are "Le Vol des Oiseaux," "Les Orthoptères et les Hélicoptères," "Les Aéroplanes sans moteurs," "L'Aéroplane," "La Manœuvre de l'aéroplane," and "Le Rôle de l'angle d'attaque." About 80 pages at the end are devoted to theory in the shape of concise notes, which should be of considerable value to lecturers and engineers. We have studied the book very carefully, and have no hesitation in according it the highest possible praise.

Aeronautical Classics.—No. 3. "The Art of Flying." By Thomas Walker. (London: Aëronautical Society of Great Britain, 1910; 1s. net.)

The third number in this series, which has met with a gratifying reception from the Press, and is being translated into French and Russian, is a reprint of both the original editions (1810 and 1831), with all the illustrations and facsimiles of the title pages. It is to be hoped that the care and trouble obviously expended by the honorary editors upon this admirably got-up series will be rewarded by the support of all members. The profits (if any) are being devoted to the upkeep of the Library.

Model Balloons and Flying Machines. By J. H. Alexander, M.B., A.I.E.E. (London: Crosby Lockwood, 1910. 3s. 6d. net.)

The *raison d'être* of Mr. Alexander's little book is the instructions for building model flying machines, which are elaborated by five sheets of working-drawings. These are quite good, and the directions given are particularly clear and explicit. The historical part of the book does not call for serious criticism. Most of the proper names are wrongly spelt, and, among other things, the statement that "the brothers Tissandier, in 1875, voyaged, in 24 hours, in an airship from Paris to Bordeaux" seems to call for some explanation.

Bibliography of Aeronautics. By Paul Brockett. (Washington: Smithsonian Institution; London: W. Wesley, 1910. 8s. 6d. net.)

The Smithsonian Institution, to which aeronautical science owes so much, has increased the debt by the publication of a monumental Bibliography of Aeronautics. Mr. Brockett, the Assistant Librarian of the Institution, who edits the volume, deserves well of the whole aeronautical world. His immense labours are amply demonstrated by the fact that there are 13,487 entries covering the subject up to July, 1909. The book will be invaluable to librarians, pressmen, and all those in any way interested in the science.

CORRESPONDENCE

"THE FLIGHT OF BIRDS" AND "THE CONQUEST OF THE AIR"

To the Editors of the *Aëronautical Journal*

SIRS,—It is to be wished that the writers of aeronautical papers, when they do find it necessary to introduce considerations involving mathematics or theoretical mechanics, would give rather more attention than they sometimes do to seeing that their statements are clearly and explicitly put forward.

On page 63 of the April issue appears the statement, regarding bird flight: "When the wings strain forward the centre of gravity moves forward slightly. When the wings move backward for another stroke the centre of gravity moves slightly in the same direction." This statement appears at first sight at variance with the fundamental laws of mechanics, and, indeed, I fully believed at first that it was absurd. What was probably meant was

somewhat as follows: When the wings move forward the bird's motion is being retarded; when they move backwards it is being accelerated. The result is to produce an oscillatory motion of the centre of gravity in addition to the uniform motion of translation. But in harmonic oscillations the displacement is in the opposite direction to the acceleration. This gives a forward displacement of the centre of gravity in the forward stroke and a backward displacement in the backward stroke as stated.

As another instance, I would call attention to the correspondence on page 89. It seems fairly obvious that the trouble has arisen largely, if not entirely, through a confusion between "motive force" and "horse power," the former of which is equal and opposite to the resistance to be overcome, while the latter is equal to the former multiplied by the velocity of its point of application multiplied by a certain constant. With resistance varying as the square of the speed the motive force will vary as the square and the horse power as the cube of the speed. In neither of these cases is the meaning very obvious without some such explanation.

G. H. BRYAN

EMANUEL SWEDENBORG'S MSS.

SIRS,—I have pleasure in forwarding to you a translation of the notes that you ask for. The original of the document preserved at Linkoping may be seen in facsimile at the Swedenborg Society's House at No. 1, Bloomsbury Street. I am not sure that they have a copy of the Dædalus, in which the published account appeared, but there is a copy in the British Museum. I think it is to be found under the head of Periodicals. It is an exceedingly rare work. It is to be published in facsimile by the University of Upsala as a part of their celebrations of the bi-centenary of their Scientific Society. It is not, however, to be ready till November.

JAMES R. RENDELL

ANALYSIS OF FOREIGN PUBLICATIONS

ABBREVIATIONS

Aeron., Aeronautics (New York)
Aircraft, Aircraft (New York)
C.-V., Le Cerf-Volant (Paris)
D.Z.L., Deutsche Zeitschrift für Luftschiffahrt (Berlin)
Flug, Flug und Motor Technik (Vienna)
L'Aér., L'Aéronaute (Paris)
L'Aérop, L'Aérophile (Paris)
Rev. Aér., Revue Aérienne (Paris)
Rev. de l'Av., Revue de l'Aviation (Paris)
Tech. Aér., La Technique Aérienne (Paris)
W.L.Z., Wiener Luftschiffer-Zeitung (Vienna)

AERODYNAMICS

Du rôle du vent dans l'aviation. (Lorenc.) "L'Aérop." May 15
Etude des parcours aériens. (Delens.) "L'Aérop." June 15
Recherche du centre vélique en aéronautique. (D'Amans.) "L'Aér." April 30
Sinusproblem und Verhältnis der Flugarbeits-grössen bei ebenen und gewölbten Flächen. (Lynkeus.) "Flug." May 10 and May 25
Sur la résistance de l'air. (Bourlet.) "L'Aérop." April 15.
Sur l'équilibre et la descente rectilique de l'aéroplane. (Lecornu.) "L'Aér." April 30

AEROPLANES

L'Aéroplane Drzewiecki. "L'Aér." June 25
L'Aéroplane G. Brunet. "L'Aér." April 30
L'Aéroplane "Louis Bréguet." "L'Aérop." June 15
L'Hydro-Aéroplane "Henri Fabre." "L'Aérop." June 1
Le biplan Maurice Farman. "L'Aérop." June 1
Le Monoplan "Etrich 1910." "L'Aérop." June 15
Le Monoplan "Paul Zens." "L'Aérop." May 15
Le nouvel aéroplane de Sir Hiram Maxim. (Espitallier.) "Tech. Aér." April 15
The Baldwin Biplane. "Aircraft." July
The Thomas Biplane. "Aeron." June

ATMOSPHERE

Beobachtungen über die Lichtintensität bei einer Ballonfahrt. (v. Schrötter.) "W.L.Z." July 1

BIOGRAPHY

André Noël. "L'Aérop." July 1
A. von Pischoff. "W.L.Z." June 15
C. E. Guillaume. "L'Aérop." June 1
Emile Dubonnet. "L'Aérop." April 15
Henri Rougier. "L'Aérop." May 15
Hudson Maxim. "Aeron." June
H. W. L. Moedebeck. "D.Z.L." May 18
O. Chanute. "L'Aérop." June 15

BIRD FLIGHT

L'Aigle de Mouillard. (Roux.) "L'Aérop." June 15
L'Aigle de Mouillard. (Thouveny.) "L'Aérop." May 15
La Mécanique et le vol des oiseaux. (Thouveny.) "L'Aérop." July 1
Note sur la tenue des oiseaux dans l'air. (Langley.) "Tech. Aér." June 1

CONSTRUCTION

Observations relativement aux "Rendements de construction" dépassant la valeur de l'unité. (Lorenc.) "L'Aér." May 28
Sur la cause des ruptures des pièces de construction dans les navires aériens. (Bourgey.) "Tech. Aér." May 1

DIRIGIBLES

La Flotte Aérienne Allemande en 1910. (Rückstuhl.) "L'Aérop." May 15
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La Stabilité automatique des Aéroplanes par l'emploi de plans fixes verticaux. "L'Aér." June 25
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